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THE MARCH SCIENTIFIC MONTHLY

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THE SCIENTIFIC MONTHLY

MARCH, 1929

RECENT GEOLOGIC EXPLORATIONS IN CENTRAL ASIA[1]

By Dr. CHARLES P. BERKEY

COLUMBIA UNIVERSITY

THIS evening I want to introduce you to the continent of Asia, and to that end I propose to practice a little magic, an art not at all strange to the land I hope to have you see. Following the approved method of magicians I must tell first what is to happen, and then I shall expect every one to become convinced that it has been done.

We shall all go together on a long journey. No one need make special preparation, for it will make no difference how fast we go or in what manner, just so by this means we may see the continent of Asia and begin our acquaintance with a fascinating and too-little-known portion of the earth.

Now let us be off. I shall act as conductor and describe the more significant features as we come to them. This is the most approved method in geology anyway, for it is comparatively easy to keep our bearings in that way, passing from the well known of our own home town to the little or entirely unknown and untried trails of strange lands.

At first the scenes are all familiar. The verdure-covered mountainous belt of the Highlands of the Hudson and the Catskills, with the Appalachian mountain ridges stretching away to the southward, are soon left behind. Then the Great Lakes, and next the enormously broad, monotonously level, unbelievably productive farm country of the Mississippi Valley rolls away for a thousand miles, rising ever so gradually westward until it merges imperceptibly into the Great Plains beyond. By and by even the seemingly interminable plains stop abruptly against the great natural barrier of the Rocky Mountain front, and the easy going is at an end. But one may mount this range as the airplanes do and thence continue for other hundreds of miles over one mountain range after another, with their alternating intermont parks and rich valleys, to a series of desert basins, beyond which lies the second great mountain barrier, formed by the imposing Sierra Nevada guarding the Pacific slope. Here again, however, it is but a simple matter for us to mount this last barrier and glide down over its long ragged western slopes to the level of the sea.

Although this looks like the end, our real journey has only begun. Here we must take ship and sail out through the Golden Gate, for the objective is across the seemingly boundless Pacific, on the other side of the earth. In less than a week one comes to islands that rise

[1] Address at the first general session of the New York meeting of the American Association for the Advancement of Science, given at the American Museum of Natural History on the evening of December 27, 1928.

—From the American Museum of Natural History

SKETCH MAP OF THE COAST LINE

AT THE BEGINNING STAGE OF THE GREAT PLAIN OF CHINA, BEFORE THE RIVERS HAD ACCOMPLISHED MUCH DEPOSITION OF SILT. PREPARED BY F. K. MORRIS.

abruptly out of the sea as if they were mountains standing there. And so they are—enormous volcanic mountains built up on the ocean floor by the accumulation of lavas and other volcanic débris until they have reared their summits above the waters of the deep and reach far into the clouds. Here one may see volcanic activity in its most impressive form still operating, and a mountain still growing with the material erupted from the interior of the earth. These are the Hawaiian Islands, a virtual island paradise in the mid-Pacific.

In another two weeks one comes again to islands that appear as abruptly as the volcanoes of Hawaii. This time they are mountain ranges that have been drowned in the sea. They are more complex in their structure and history, much higher and much larger than those of Hawaii, but again they impress one chiefly with their great relief and ruggedness. These mountainous islands, with their terraced farm plots clinging to their lower slopes, we call Japan.

From Japan we sail through the inland seas between and around these drowned mountain-range islands into the China Sea, which separates Japan from the continent of Asia. For two days we may sail over waters as blue as the ocean affords, and then, as the ship plows its way toward Shanghai, the waters change color. By and by they have turned a dirty yellow—as yellow as waters can be. I knew, of course, as a boy that this was called the Yellow Sea.

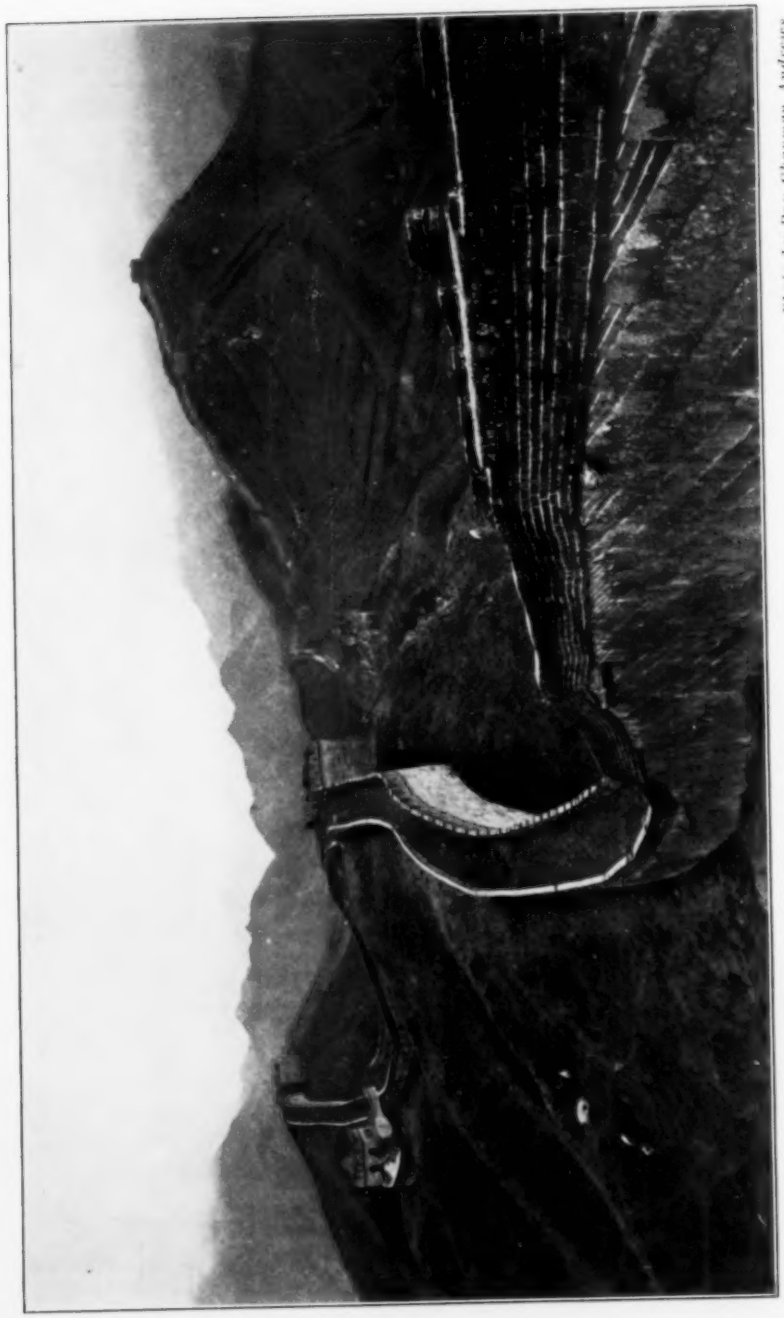
but I supposed it was because the yellow races lived on its borders. Now I know that it is called the Yellow Sea because it is yellow. And the sea is yellow because of the enormous quantities of silt which the rivers of Asia carry down from the interior of the continent. The yellow dust, called loess, that has been swept out of the deserts by the wind is picked up again by the rivers and is carried out into the sea miles and miles before settling. When it does settle out it accumulates on the floor of the sea, little by little, time without end, one century after another, until ultimately the deposits build to the very surface of the sea. So places where the sea once stood become land which the rivers overflow and build up still more. This work the rivers of Asia have been doing for ages, pushing the borders of the land further and further out into the sea. They have actually built these lands that are known as the plains of China.

So, when one comes in sight of land again, it is just as different from the islands seen before as a land can be. That low dark streak on the horizon emerging from the haze hardly above the level of the sea itself is land—the first glimpse of the continent of Asia. This is the outer margin of the great plain of China. It is as flat and level as a floor, and so low-lying that one almost expects it to be inundated by the next tide or to be overflowed by the Yangtse River in flood season, ready to spread a new layer of silt over the face of the plain. Such things have happened year after year, literally for ages, making this one of the

—*From the American Museum of Natural History*

SKETCH MAP OF THE CHINA COAST TO-DAY

SHOWING THE GREAT PLAIN WHICH HAS BEEN BUILT UP BY THE RIVERS COMING FROM THE INTERIOR. (COMPARE WITH SKETCH MAP SHOWING BEGINNING STAGE.) PREPARED BY F. K. MORRIS.



—*Photo by Roy Chapman Andrews*

THE GREAT CHINESE WALL

WHICH FORTIFIES THE MOUNTAIN BARRIER BACK OF PEKING.

richest and most extensive alluvial plains known on the face of the earth.

Pushing on from Shanghai, one sees only this monotonous plain, but in the course of time he comes to hills that emerge as abruptly from the plain as the islands of Hawaii or Japan did out of the sea. That is because they once were islands themselves, standing in the sea, and the plain that now surrounds them has been built by the rivers with their loads of silt deposited in the surrounding waters of a former time, just as is now happening out in the sea beyond Shanghai. Therefore one may now walk over to the hill that once was an island instead of swimming to it, as he used to do.

So one continues his journey over low-lying country northward to the Shantung peninsula. This fine province with its sacred mountain, Tai Shan, was once a mountainous island lying out in the sea just like the islands of Japan. But the Yellow River filled up the depths of the sea and built this plain around it, adding it all to the continent of Asia.

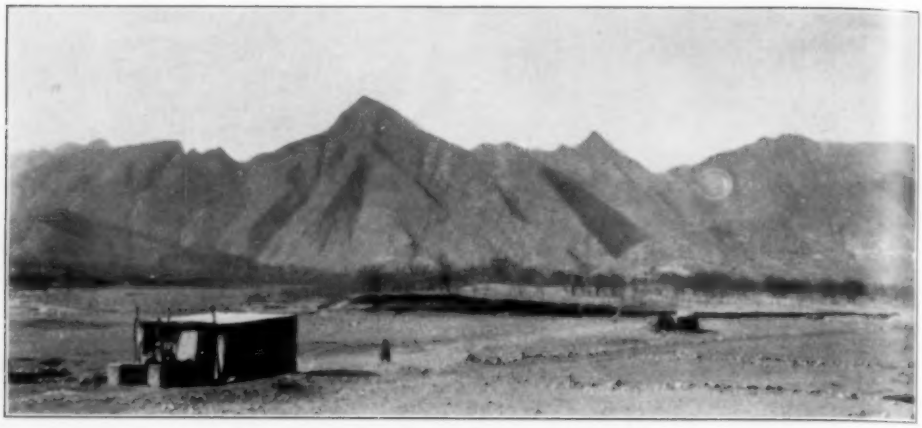
Once over this partially buried mountain range one comes down to the plain again, crosses the Yellow River and is off to Tientsin and inland to Peking, the old capital of China, from which point one must make a new start. Now after a journey that has taken two days one is astonished to find that he is still on the Great Plain of China and only a hundred and fifty feet above sea-level, although he has journeyed nearly a thousand miles.

But if one goes beyond Peking only an hour's journey, a great change takes place; a high mountain range rises almost as abruptly as a monster wall. This is the natural protective barrier for the people of the plain. To go further into Asia one must find one of the very few passes which penetrate this exceedingly rugged and difficult range. Here it is that the Chinese have built their Great Wall as an extra protective measure. We shall take Nan K'ou Pass, the only one within reach, and the same through which the hordes of Mongol invaders from Central Asia came down in ancient times under Genghis Khan, "The Emperor of all Men," when they overran China.

This time, after reaching the head of the pass two thousand feet above the plain, one does not come down again, but continues westward almost on a level with the mountains as if on a great terrace, a half day's journey farther inland to Kalgan, the last city on the very borders of the unknown. Here one faces a second great mountain barrier that rises another three thousand feet, presenting the same forbidding appearance as that protecting Peking.

Now one must put off the luxuries of civilization and adopt the primitive ways of all frontiers. So we must take to our field equipment and begin our real journey of exploration. It is possible that some of us may not return, but if and when we do return we shall have had our try at one of the most interesting exploratory experiments of modern times. The camel caravan with supplies has already been long on the trail. They must be several hundred miles out, so we can afford to use the best devices of modern invention for swift travel to save the time and energy of the scientists who are to unravel the story of the wastes beyond the mountain barrier.

If one goes farther these heights must be scaled. The trail is rough, almost impassable, as one follows the boulder-strewn bed of a stream course and climbs the last three thousand feet to the very top of the range. And then a surprising thing happens. One finds that he has not climbed a real mountain range at all. Instead he finds himself on the edge of a great plateau, which stretches out into rolling landscapes as far as the eye can reach. It was only



THE WESTERN HILLS BEYOND PEKING

THIS MOUNTAIN RANGE FORMS THE FIRST GREAT BARRIER TO TRAVEL TOWARD THE INTERIOR OF ASIA.

the rugged, deeply eroded face of this plateau that looked like a mountain range from the valleys below.

This is the inner border of Mongolia; the edge of one of the great interior basins characterizing Central Asia. This is the gateway to the Desert of Gobi. For nearly a thousand miles these rolling landscapes stretch out to the north, and for more than three thousand miles east and west. This is the land we have traveled so far to see. This is the region where the Central Asiatic Expeditions spend half a year at a time entirely out of touch with the civilization that we know. The people of this strange land maintain the customs of a thousand years ago. It is an easy step here to the much more ancient records preserved in the rocks of the earth itself.

It is not sufficient for our purpose, however, to know that this is the Desert of Gobi. That has been known ever since man first found his way across these barren tracts in prehistoric times. Men have lived here probably about as long as they have lived anywhere. These wastes have seen one people after another develop and prosper under the favor of kindly times, only to be driven out in its periods of severity, marked by reversion to desert climate. So the migrations began that have changed the face of one civilization after another ever since the dawn of man. Therefore it is not at all an unknown region. Travelers and adventurers and merchants have followed these trails ever since man began trading with his neighbor beyond the Great Wall. The nature of the land itself and its people were known, but the things belonging to its scientific story have remained hidden in a record that no untrained man could read.

Before I go into that matter further I must explain what the Desert of Gobi is like and why one goes there to carry on scientific explorations. Why should any one pick out this desolate place?

Once upon a time, geological ages ago, this portion of the earth was mountainous, with all the complicated structures that belong to such a region; its mountain ranges stood as high and as rugged as any others of their kind. But they were so long exposed to the destructive attack of the weather and the erosion, the winds and the rains, that the moun-

tains were literally worn away. The rivers of that time carried to the sea one particle after another, loosened by weathering, until the whole mass was worn down. The result was as if one had taken a great hand plane and had shaved off the elevated portions, throwing the handfuls of shavings away into the sea to help build up there the lands that eventually made the rest of the continent that is now Asia.

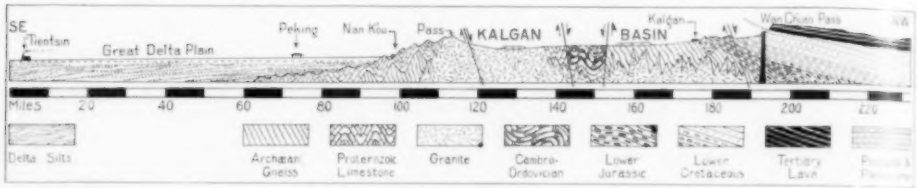
These erosion processes continued, year after year, age after age, until the surface of the land became like a great floor beveling across the roots of the ancient mountains, the tops of which had been carried away. It must have been a low-lying land, not very much above the sea-level of that time. It must have looked like the end of all things, but in reality its most interesting happenings had just begun. With the help of subterranean forces, the character of which is not very well understood, the whole central portion of the continent, hundreds of thousands of square miles in area, was lifted high above its former level. But the outer edges were raised higher than the middle portion, which sagged a little, so that the whole area took on a basin-like form. Then the streams that aforetime flowed out of this region, carrying their load of sediment to the sea, turned inland and deposited their burden upon the bottom of the basin. There, on the old erosion floor, these new sediments have been accumulating, one layer on top of the other, ever since that time. These are the so-called Later Sediments of the Gobi region.

Because the borders of the basin are higher than the interior, half a mile higher, the moisture-laden winds from every direction precipitate rain and snow there and pass to the interior as drying winds. So these borders are comparatively fertile and reasonably prosperous, whereas precipitation fails in the interior, and this portion is desert. The Gobi is only one of a series of similar desert basins stretching across Asia.

The story would be comparatively simple—but exploration nearly hopeless—if it had not been for the renewal of uplifting and deforming movements. From time to time after deposits began to accumulate, portions of the basin were deformed. In certain places it was depressed still more, and in other places the floor was lifted so that smaller basins and intervening bulges were formed. Then the sediments that had already collected were eroded from the uplifted

THE GREAT WALL AT KALGAN

THIS SHARP-POINTED WALL LENDS PROTECTION TO THE CITY OF KALGAN.



—From the American Museum of Natural History

DIAGRAMMATIC CROSS-SECTION

FROM THE COAST AT TIENTSIN TO THE BORDERS OF MONGOLIA AT WAN CH'UAN PASS, SHOWING THE FOUR GREAT STEPS IN REACHING THE INTERIOR: THE GREAT PLAIN; THE FIRST MOUNTAIN BARRIER; THE KALGAN BASIN; THE SECOND BARRIER FORMED BY THE EDGE OF THE PLATEAU OF MONGOLIA. THE CHANGES IN UNDERGROUND STRUCTURE ARE ALSO INDICATED. DRAWN BY F. K. MORRIS.

portions and were redeposited in the adjacent deepened basins, forming a second layer of Later Sediments there. Such disturbances as these have continued to the present day, accompanied by corresponding shiftings of erosion and deposition to match the warpings of the basin floor. As a result one may now cross many large areas where the ancient floor is exposed, and pass from these on almost the same level to similar large areas of smooth ground underlain by accumulated sediments. As the result of such history the sediments in many places are thin and represent only a small fragment of the whole story. In other places they are comparatively thick and successfully record long chapters of geologic history.

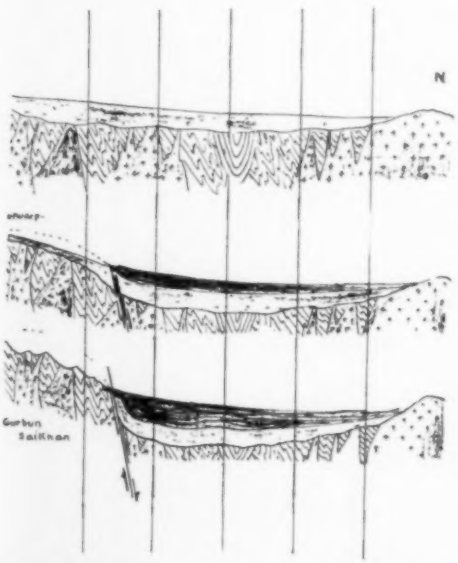
From the very beginning of this continental history, ever since these basin sediments began to form, geologic ages ago, this portion of Asia has remained above sea-level. The animals that roamed over these plains were never driven out by the sea, although they may have been forced at times of great aridity to migrate to more hospitable adjacent lands. Here they lived and here in these sediments their bones are buried with the rest of the débris. The strange creatures that inhabited this interior region for tens of millions of years are represented in the fossil remains. Some of them were drowned in the rivers; some sank to their death in treacherous quicksands; others mired in the borders of muddy lakes and their bones were covered by the silts that were washed in so that now they lie buried as fossils in these sediments, and yet others died in the open and were covered by drifting sands.

If the strata were not exposed there would be small chance of recovering many of these remains, but wherever there has been deep erosion, or wherever the strata have been warped up or faulted so that their edges are exposed, there it is worth while looking. Then if a good place is found where the bones are well preserved and if one knows the value of bones when he sees them, it is possible to discover a new type or secure a whole museum full of material.

It all looks simple enough after the story is unraveled, but it is a hopeless outlook as one for the first time faces the discouragements of a desert waste and the uncertainties of wholly unknown ground. After the key is discovered and the elements of the history are determined, one may traverse a hundred miles with entire confidence that there is no need to search for fossils there, for this is the ancient floor. On another stretch, recognized as underlaid by Later Sediments, one can be equally cer-

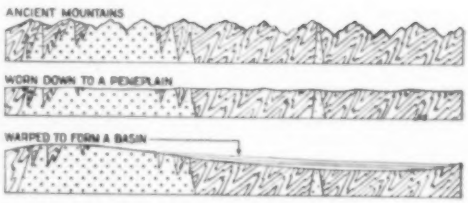
tain that it is promising ground and that one must stop and inspect the strata beneath if a place can be found where erosion has exposed them. Valley-side bluffs, gulches and badlands are all closely scanned. If fragments of bone are found the search is continued, and partially exposed remains are excavated with the greatest care.

Through the work of the Central Asiatic Expeditions it is now known that Central Asia has some of the finest fossil fields in the world. When the work began no one knew that. Yet Central Asia had been known since earliest times. These deserts lie athwart



DEVELOPMENT OF A SEDIMENTARY BASIN

DIAGRAMMATIC SKETCH SHOWING THREE STAGES: (TOP) THE FIRST SEDIMENTS BEING LAID DOWN DIRECTLY UPON THE SMOOTHED FLOOR OF ANCIENT ROCKS; (MIDDLE) THE BASIN DEEPENED BY FAULTING SO THAT THE SEDIMENTS AT THE LEFT WERE CARRIED OFF AND DEPOSITED ON THE DEPRESSED PORTION AS A NEW OVERLYING FORMATION; (BELOW) THE SEDIMENTS ENTIRELY SWEPT FROM THE UPLIFTED AREA AT THE LEFT AND ACCUMULATED AS A THIRD FORMATION ON THE DEPRESSED BLOCK. DRAWN BY F. K. MORRIS.

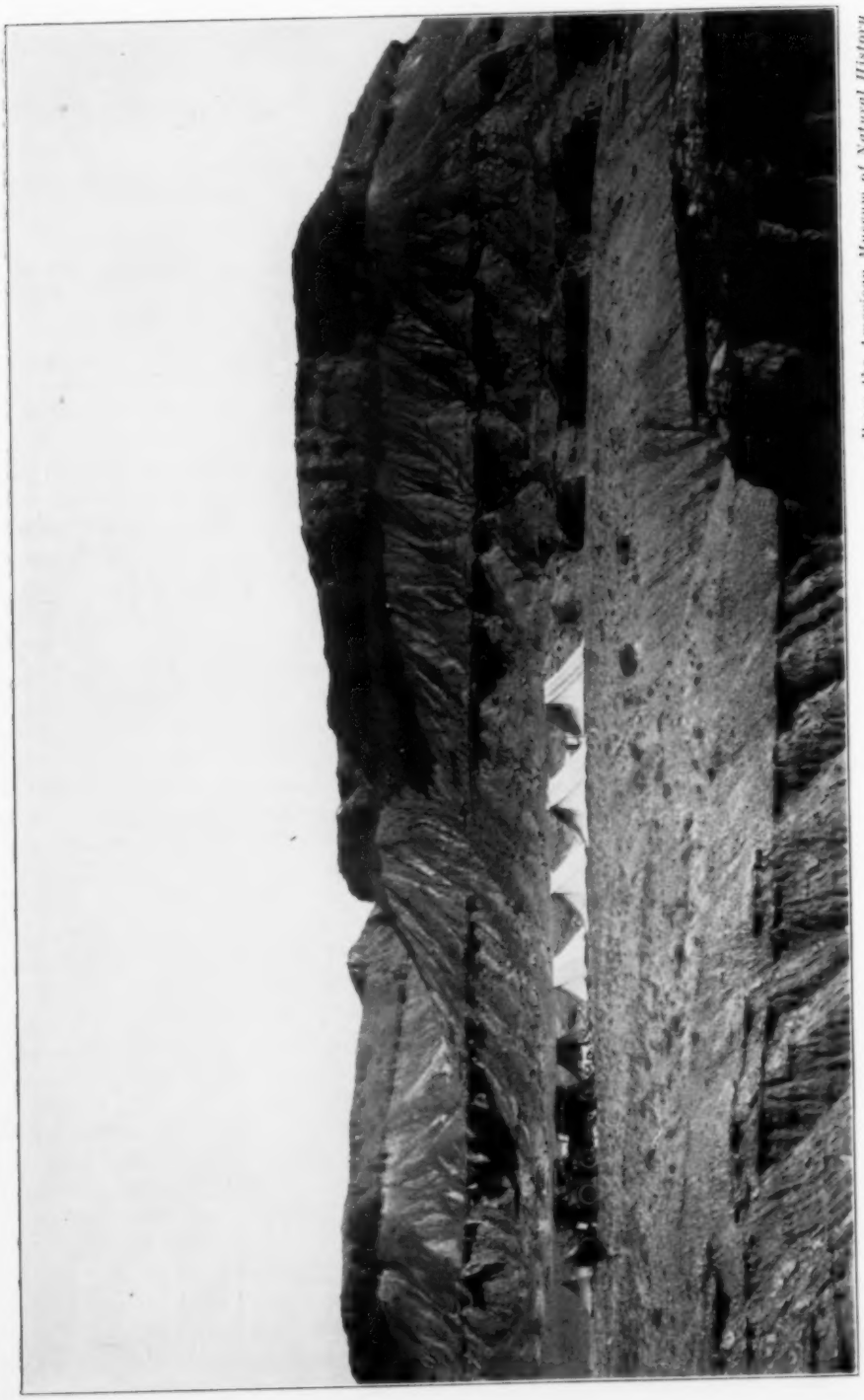


DIAGRAMMATIC SKETCH

SHOWING THREE STAGES IN THE DEVELOPMENT OF A SEDIMENTARY BASIN FROM A MOUNTAINOUS AREA. DRAWN BY F. K. MORRIS.

the trade routes of the ancient world, and they have been traversed ever since commerce began. One people after another has occupied this region from prehistoric times, so it is not a *terra incognita* in that sense. Only its scientific elements were unknown. The traveler of modern times found enough privation and danger in this forbidding country to occupy his whole attention, and he was glad to escape with his life. The drifting sands, the terrific unabating winds, the burning sun and the barrenness and emptiness impressed him, but the records in the earth beneath his feet and the evidence to be found there bearing on the manner in which these desert lands were made and the kinds of animals that lived there in past ages made no appeal. So despite thousands of years of history and tens of thousands of prehistory, the scientific story of the Gobi desert was until recently almost as unknown as it was in the time of Adam.

Within a week of the time the expedition started, on one of the ancient Tartar trails over which caravans have traveled for thousands of years, and within a hundred yards of the well at Iren Dabasu where all these travelers have camped from time immemorial, the first dinosaur bones were found, the first ever found in Central Asia. Of course no one before had been looking for bones; no one had any particular use for the stray bones of animals dead as long



—*From the American Museum of Natural History*

A DESERT CAMP

IN THE BACKGROUND ARE BRIGHT RED CLIFFS, CAPPED WITH BLACK LAVA. THE FLAT-LYING SEDIMENTS BELOW CARRY LAYERS OF HARDER AND SOFTER STRATA, YIELDING DIFFERENTLY TO EROSION AND GIVING STEP-LIKE BENCHES. DEEP WIND AND WATER ARE CONSTANTLY AT WORK DESTROYING THE BEDS THAT FORMERLY EXTENDED CONTINUOUSLY ACROSS THIS DESOLATE

as these. Only a scientist finds such things interesting and worth while. It is not quite clear to the native to this day why any one should do so useless a thing, or anything else for that matter which does not have to be done.

The Asiatic Expeditions, however, were organized to do just such work. Beginning in a very unpretentious manner, they were at first largely concerned with collecting exhibits and study collections for the American Museum of Natural History in New York City. The first two expeditions—those of 1916 and 1919—were planned, organized and executed by Roy Chapman Andrews, acting in all capacities—as originator, leader, transportation and diplomatic director, foreman and the whole scientific staff himself. The scientific venture was modest, and the traverse had to be limited to the trails that men may follow with some assurance of safety.

It had become apparent, however, that Central Asia, with its scientific story almost unknown despite its long human history, presented a real opportunity. This was true partly because its people have cared much for art, philosophy, literature and religion but little for science. And it was true partly also because of the comparatively inaccessible and inhospitable nature of the interior of Asia. Otherwise, foreign travelers—called explorers when they become students of little-known physical conditions in out-of-the-way places—would have studied the region long ago. Those more adventurous individuals who had penetrated portions of this vast interior basin country had found it quite impossible to make systematic investigations extended enough to construct a connected and comprehensive story.

On the more hospitable borders, however, such work had been going on for many years, and significant and valuable contributions had been made. The most outstanding were those of the late Raphael Pumpelly, the veteran American geologic adventurer; of von Richthofen, the pioneer German explorer; of Obruchev, the great Russian geologist, who penetrated far into the desert country of both the Gobi and Dzungaria; of Sven Hedin, the famous Swedish explorer, whose delightful accounts of his travels among strange surroundings, especially in the high plateaus of Tibet, are classic; and of Dr. Bailey Willis, another American geologist, whose researches in China are fundamental studies. These deserve more recognition than any others, although there were many others. Their works were the chief guides for those bent on exploration. One could begin there.

After two years of preliminary work along the borders between the slightly known and the almost wholly unknown regions, Mr. Andrews began planning for a third expedition. It had become clear both to him and to his chief sponsor, Prof. Henry Fairfield Osborn, president of the American Museum, that a more elaborate expedition was fully warranted. Professor Osborn had long held that Central Asia was likely to produce valuable evidence in the story of the evolution of the vertebrates. Thus it happened that the Third Asiatic Expedition, that of 1922, became an exploratory investigation so constituted and operated as to make feasible the penetration of otherwise inaccessible territory, covering many times more ground than had ever before been possible in a single season.

The study of the geologic and paleontologic history of Central Asia was begun that season, and has been continued ever since, with additional field work in the summers of 1923, 1925 and 1928. In 1925 archeological and botanical studies were added. Each time large collections of rocks, fossils, animals and plants were made. Each time, also, more or less elaborate investigations were suc-

IN THE BACKGROUND ARE BRIGHT RED CLIFFS, CAPPED WITH BLACK LAVA. THE FLAT-LYING SEDIMENTS BELOW CARRY LAYERS OF HARDER ASH BEFORE STREAMS, YIELDING DIFFICULTLY TO EROSION AND GIVING STEP-LIKE BENCHES. HERE WIND AND WATER ARE CONSTANTLY AT WORK DESTROY-ING THE BEDS THAT FORMERLY EXTENDED CONTINUOUSLY ACROSS THIS LOCALITY.

ROY CHAPMAN ANDREWS, LEADER (RIGHT) AND F. A. LARSEN, INTERPRETER
EXHIBITING ONE OF THE LARGEST BIRDS OF THE GOBI REGION.

cessfully carried on in the field, and material was gathered for the continuation of such studies in the laboratory.

As long as running accounts of progress or special notices of particular finds were the chief matters published, the individual character of successive expeditions could be emphasized. In this way the Third Asiatic Expedition came to be widely known. But as soon as more formal publications were undertaken, especially where summaries of results were included, it was clear that distinctions between the different expeditions could not be maintained, and that a more general designation should be adopted. For this reason, the more comprehensive name, the Central Asiatic Expeditions, has been applied to the whole series, both for the field work and for publication.

Perhaps a bird's-eye view of operations should be given to furnish the picture a matter-of-fact background. The expeditions have covered approximately 25,000 miles of traverse across little-known or wholly unknown territory. Approximately 1,700 miles of route traverse have been mapped with considerable reconnaissance accuracy by topographic methods, and more than 5,000 miles of traverse have been covered with geological structure sections, while more than 2,000 square miles, distributed in twelve separate areas, have been mapped geologically in considerable detail. More than 260 cases of fossils have been recovered, in addition to botanical, zoological and archeological collections. These collections are of quite indeterminable value. Much of the material is absolutely new to science, so that there is no basis of estimate or comparison.

These are the more obvious statistical facts, but back of them is a story that reaches out into many fields of science. One of the strongest points of the expedition is the fact that the field work was done by the whole group together.

GEOGRAPHY

There were maps of Mongolia before, but they were all bad. The major

routes of caravan travel cross the region about where these maps indicate, and most of their mountain ranges exist, but they are never at the right spot. Sometimes they do not even show the right course, and none of the detail is dependable. On this account the maps and other geographic observations of the expedition constitute valuable data, usable for correction purposes.

A large number of route maps and detailed locality maps were produced. Those of the season of 1925 were made by Major L. B. Roberts and those of 1928 by Capt. W. P. T. Hill. About one thousand miles were covered in this manner, beginning at Kalgan and reaching beyond Kholobolchi Nor, not far from Uliassutai. Locations were derived from solar observations; distances were kept by automobile speedometer; orientation was obtained independently of possible magnetic variation by means of solar chart; differences in elevation were secured by vertical angles, and, in general, plane table methods were used.

Detailed topographic maps of five type areas were made with an accuracy comparing favorably with the topographic sheets of the U. S. Geological Survey. These furnish excellent base maps for other branches of the work, particularly for geology and paleontology.

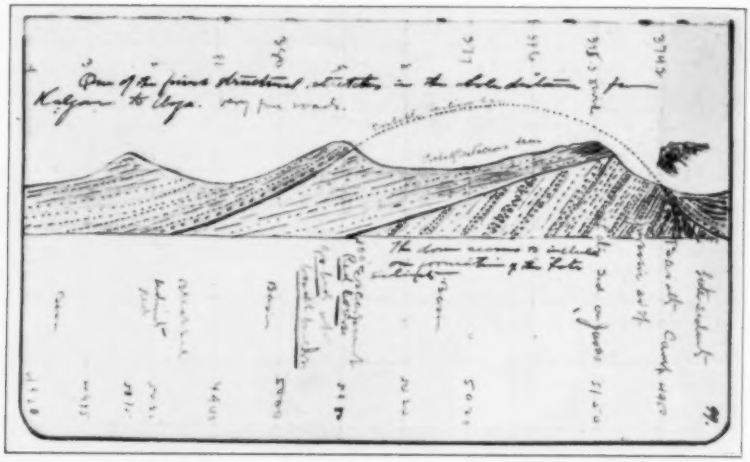
Geology

The Central Asiatic Expeditions have made two notable contributions to geology. Of these the more tangible is represented by the classification of

—From the American Museum of Natural History

FOSSIL BONES

A GROUP OF BONES PARTLY UNCOVERED AND STILL IMBEDDED IN THE ROCK WHERE THEY WERE BURIED AGES AGO, SHOWING HOW PLAINLY MARKED AND HOW WELL PRESERVED MANY OF THESE FOSSILS ARE.



A TYPICAL PAGE IN THE GEOLOGIST'S NOTEBOOK

A CONTINUOUS SERIES OF CROSS-SECTIONS, SUCH AS THIS, RECORD THE GEOLOGIC STRUCTURE OF THE COUNTRY ALONG THE ENTIRE LINE OF TRAVERSE, IN TEN-MILE STRETCHES. THE NUMBERS ABOVE THE SKETCH SHOW DISTANCES IN MILES; THOSE BELOW RECORD ELEVATIONS ABOVE SEA-LEVEL. THE NOTES ARE CATCH-PHRASE DESCRIPTIONS. IN THIS MANNER THE GEOLOGY OF THE WHOLE ROUTE WAS WORKED OUT AND RECORDED.

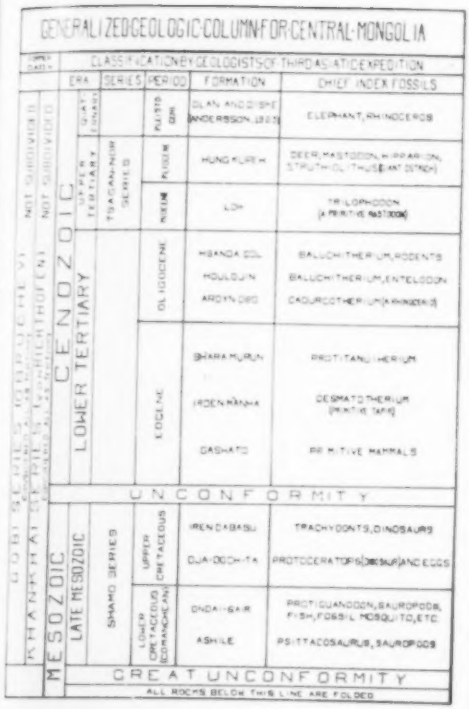
geologic formations and the mapping of rock units and structures for several thousand miles of new country. The less obvious but more valuable and difficult is the interpretation of these formations and related structures in terms of a relatively comprehensive geologic history of Central Asia, the very last chapter of which has to do with prehistoric man.

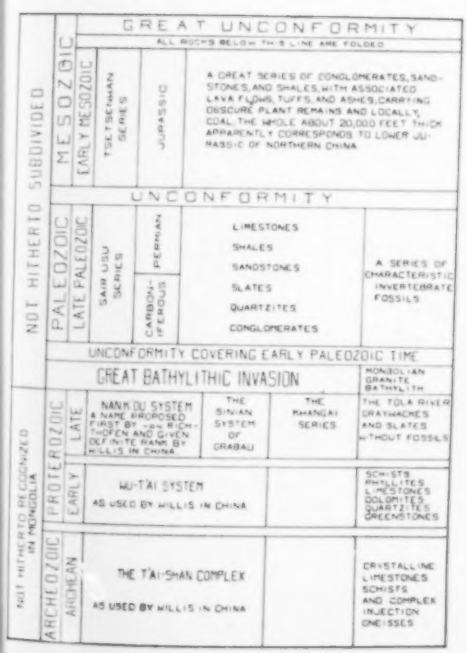
The series of geologic sections, showing the underground structure, covers more than five thousand miles of traverse, fully identified with the physical features of the country. These traverses, therefore, have become essentially geologic base lines, from any point of which new traverses may be begun. They now make a continuous section connecting Siberia on one side with the borders of China on the other, and the studies based on them have given the best understanding yet reached of the major elements of geologic structure of Central Asia.

The geologic column is now fairly well known. For the first time a systematic statement of the ages represented in the rocks of Central Asia has been compiled. The character, thickness, origin and relative age of each has been determined, and twenty-five new geologic formations have been described. The gaps in the record have been noted, and comparison has been made with the standard columns of Europe and America. Additional possibilities and critical localities have been pointed out where further work would be certain to yield results.

Geologic maps of twelve areas have been made showing the areal, structural and topographic features of type localities. A total area of more than two thousand square miles is covered in this manner.

The geologic work of the Central Asiatic Expeditions differs from much exploratory reconnaissance in that the objective kept always in view was the





interpretation of the accumulating mass of data in terms of processes and origin.

Zoology

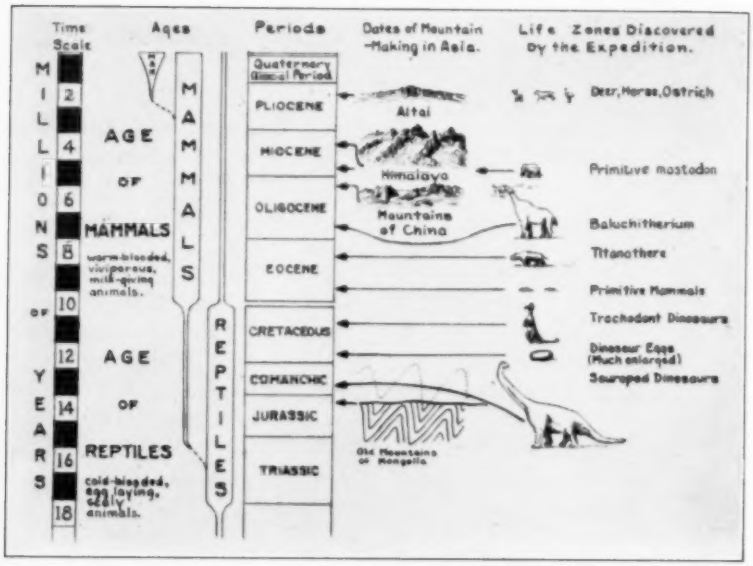
Mr. Andrews with the help of assistants made large collections of living faunas in Mongolia, and Mr. Clifford Pope conducted parallel studies in China.

Some 6,765 specimens of mammals, outside of those collected in 1928, have been deposited at the museum. Dr. G. M. Allen, who is identifying these specimens, finds the portion already worked over rich in forms new to science, no less than fifty new species and sub-species and one new genus having been discovered.

Botany

Dr. Ralph W. Chaney was in charge of botany and paleobotany on the expedition of 1925. He found that fossil plants are scarce and poorly preserved. Living species, however, are numerous and deserve additional attention. Numerous fragments of petrified wood, none of them of great size, have been collected, but no complete trunks of trees were discovered. Some of the specimens are twisted and may be interpreted as representing the growth of stems under an unfavorable environment.

The absence of leaf impressions in the rocks of Cretaceous and early Tertiary age in Mongolia is significant in view of the abundance of such remains in beds of these ages not only to the south in Asia but in western North America, as well as in the Arctic and in much of Europe. If there had been abundant forests in Mongolia at that time, there would certainly have been a better record of them left in the contemporary sediments. The negative evidence, therefore, taken in conjunction with the evidence of such plant fossils as have been found, leads to the conclusion that



—From the American Museum of Natural History

DIAGRAMMATIC CHART

INDICATING THE GEOLOGIC PERIODS AND CORRESPONDING FOSSIL CONTENT REPRESENTED IN THE LATER SEDIMENTS OF THE GOBI REGION. DRAWING BY F. K. MORRIS.

the climate in Mongolia was cool and semi-arid, perhaps not greatly unlike that of to-day.

Of modern plants, 624 specimens were collected, including approximately 500 species. The flora of the canyons and high meadows of the Altai Mountains is the richest noted anywhere in Mongolia. Trees are exceedingly scarce, but in the canyons numerous well-established cottonwoods of a new species were found, besides willows and birches. On the higher mountain sides the only conifer, a juniper known as Artsa, grows in abundance. The only trees seen in Mongolia outside of the mountain canyons were scattering elms (*Ulmus pumila*), along watercourses or former streams.

PALEONTOLOGY

Paleontologic investigations were in charge of Walter Granger, who has been on each of the Central Asiatic Expeditions, beginning with 1922. President Osborn, on whose faith the venture was launched, visited the Iren Dabasu district, the place where the first finds were made, and Dr. W. D. Matthew and Dr. W. K. Gregory have done a great deal of work on the collections returned to the museum.

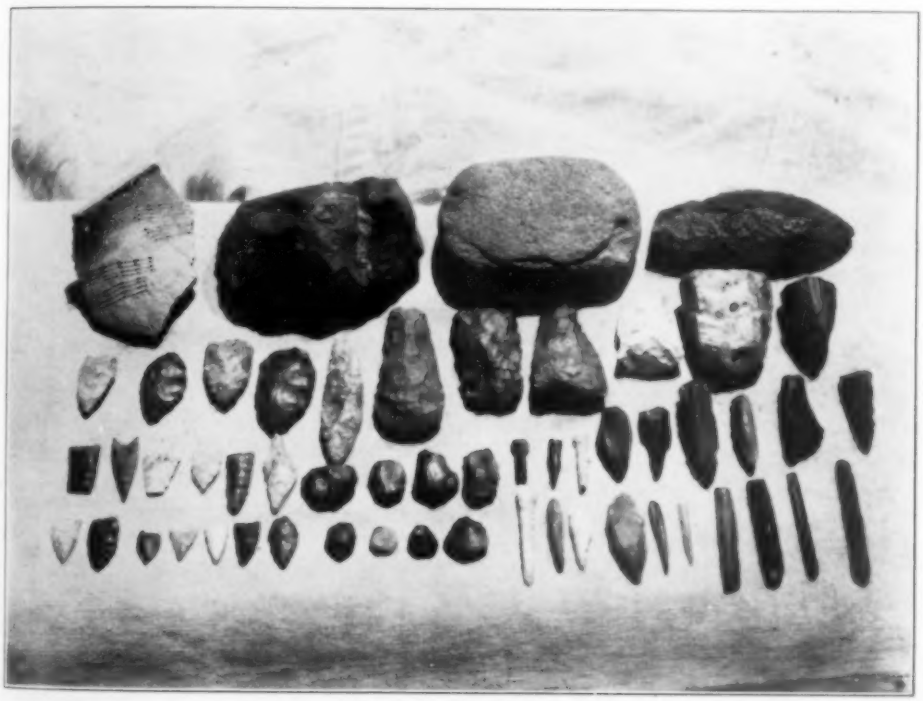
A whole new world has been opened up to the paleontologist by the discovery of a long succession of continental deposits bearing fossil vertebrates, especially mammals and reptiles, and, in addition, a well-determined sequence of formations, each bearing a mammalian fauna that contains some highly specialized local types and some elements of affinity to faunas of corresponding age in Europe or North America.

Much evidence is being accumulated that will have bearing on the hypothesis that Central Asia has been the principal center of origin and dispersal of mammals and the probable source of new types that from time to time have ap-

peared suddenly in the fossil record in Europe and North America. It appears probable that we have the earliest known ancestral ruminants, a more nearly direct line of ancestry of the rhinoceroses than Europe or America has furnished, and new light on the ancestry of various rodents.

The discovery of a new palæozoological region has naturally resulted in a great addition to the known fossil vertebrate faunas. All the species are new to science, the great majority of the genera are new, and several of them represent new or little-known groups of wider scope.

Owing to the extensive collections made and the expert methods of collecting, a large proportion of these new or little-known types are represented by numerous and unusually complete specimens, by skulls and skeletons rather than by the fragmentary scraps that usually are the first fruits of exploration in any new region. A series of over seventy skulls, with a dozen more or less complete skeletons of *Protoceratops*, in addition to the nests and eggs of this reptile, make its character, osteology, ontogeny and habits better known than those of any other dinosaur. Two other dinosaurs are represented by complete skeletons, small in size and primitive in character, throwing much light upon the



—*From the American Museum of Natural History*

EVIDENCES OF PREHISTORIC MAN

THESE ARTIFACTS REPRESENT THE PRINCIPAL FORMS SECURED IN THE SHABARAKH VALLEY, AND WERE FOUND IMBEDDED IN THE SAND ROCK IN SUCH A MANNER AS TO SHOW DIFFERENT CULTURE LEVELS. INTERPRETATION CAN BE MADE, THEREFORE, SO THAT THE ARCHEOLOGICAL STORY CAN BE CONNECTED WITH THE GEOLOGICAL STORY OF ORIGIN, CLIMATIC CONDITIONS AND TIME.

—*From the American Museum of Natural History*

PROTOCERATOPS, A FOSSIL DINOSAUR

SHOWING THE SKULL OF THIS RARE REPTILE, FOUND IN THE FINE RED SANDSTONE AT DJADOKHTA. THIS IS THE ANIMAL THAT LAID THE EGGS FOUND BY THE EXPEDITION.

origin and affinities of the iguanodont group.

Half a dozen mammal skulls found at Djadokhta are the only Cretaceous mammal skulls known. The Paleocene fauna, though fragmentary, is yet better material than any fauna of similar age anywhere except that of the Puerco-Torrejon of New Mexico. The mammal faunas of the Eocene period are not only large and varied but contain many skulls and a few complete skeletons besides hundreds of jaws and other fragmentary specimens. The material compares fairly well with the average material upon which our knowledge of American or European faunas of the same period is based, although that is based on the results of fifty or a hundred years of collecting and research.

A most important feature of the Mongolian collecting is that it was combined with thorough and detailed geologic field work, and in consequence the stratigraphic relations and succession of the faunas were well and accurately determined, and evidence bearing on the nature and origin of the sediments in which they were buried and the climate of the time is also available.

Thus within the space of a few years the discoveries of the Central Asiatic Expeditions have converted this region from a *terra incognita* to a country whose paleontologic record is fairly well known. Outside of western Europe,

central North America and Argentina the fossil record of land vertebrates is very incomplete. We know more about it to-day in Mongolia than in Egypt or India, and far more than in any other part of the world. The preliminary studies that thus far have been made of the Mongolian faunas have brought out only a small part of the results that will follow more thorough investigation, but they are sufficient to indicate this as the most important single piece of exploration that has ever been accomplished in vertebrate paleontology.

Archeology

Cultures of both historic and prehistoric relations were found. The historic remains include evidences of former Chinese colonization in the southern border country, represented by successive great walls, millstones, bronze objects, coins, etc.; camp sites and caves formerly occupied by the Mongols; and graves marked by upright slabs of stone, sometimes roughly shaped into human effigies, typical of the northwestern border of the Gobi and regarded as the burials of Turkic princes of the seventh and eighth centuries of our era.

The prehistoric remains include burial places of various types, pictorial rock inscriptions, quarry and workshop sites and habitation sites. The burial places are of various types, such as graves of round, oval and rectangular outlines, fenced by small stone slabs in standing position; graves of roundish outline, covered by single layers of stone slabs or boulders; grave vaults of stone,

—From the American Museum of Natural History

THE FAMOUS DINOSAUR EGGS

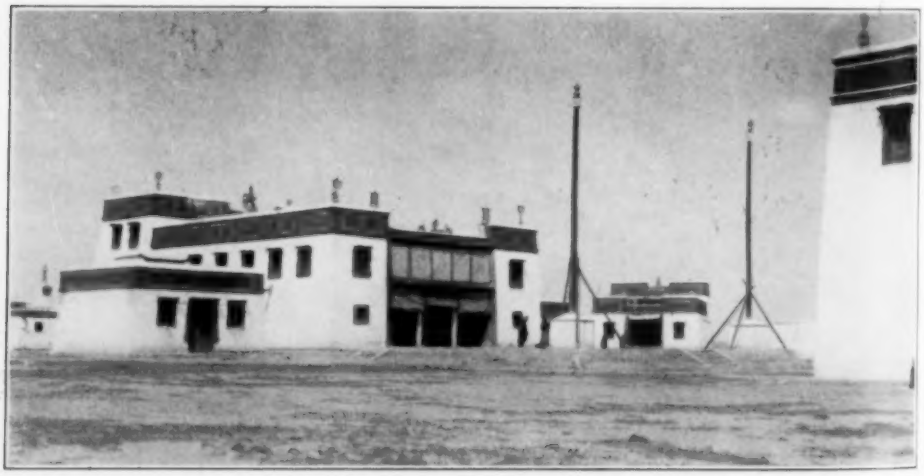
This shows a portion of a dinosaur nest with several of the eggs already exposed by erosion. The sandstone formation was originally a loose fine sand drifted by the wind, which by hardening has preserved these delicate objects. Bits of shell may be seen protruding from the rock in the background.

PILGRIM LAMAS

MET ON THE SACRED WAY BETWEEN THE TWO TEMPLES IN GOLOBAI IN OLA. THE TABLETS BEAR THE FAMOUS BUDDHIST PRAYER AND OTHER MYSTIC INSCRIPTIONS.

covered by large conical mounds (kurgans) of boulders, often inclosed by circular or rectangular walls also of boulders and of wider dimensions. A number of these burial places were opened, and a few of them yielded both skeletal and cultural remains, dating in one instance as late as the Iron Age.

The pictorial rock inscriptions represent domesticated horse and camel, and several wild animal species, some of which are locally extinct. These petroglyphs, of the type elsewhere in the world identified with the Bronze and Neolithic Ages, are intimately associated with certain of the aforementioned



ONE OF THE TEMPLES AT THE LAMASARY, TUKHUM IN SUMU

THE DECORATIVE DESIGN IS IN DEEP BROWNS AND BRICK RED. UNDER THE CENTRAL PORTICO THE WALLS ARE ORNAMENTED WITH GORGEOUSLY PAINTED MYSTIC SYMBOLS.

burial structures, and like them give evidence of considerable age.

Quarry and workshop sites were found, especially in the steppe region between Ulan Nor and the Artsa Bogdo mountain range where, for a stretch of nearly one hundred miles, red jasper and other varieties of rock suitable for flaking are exposed on the surface. The waste products of the flint worker lie here in vast quantities and the varying degrees of weather coating exhibited by the material indicate that the date of man's first appearance in the locality is of respectable antiquity. Moreover, more or less filled up by partially solidified sand dunes, called the Shabarakh formation. Embedded in this formation occur the habitation floors in question, and at Shabarakh Usu, the type locality, these floors separate into two fairly distinct and superposed cultural strata. Thus, the bottommost level is characterized by chipped flints resembling those of the extreme Late Paleolithic of Western Europe, while the upper level shows nearly all the industrial traits typical of the full Neolithic.

The special significance of the human artifacts found in Mongolia lies in the

GRANITE COUNTRY

DRIVING ACROSS COUNTRY ON THE GRANITE OF THE ANCIENT ROCK FLOOR, SMOOTHED DOWN BY EROSION

some of the finished implements found on these sites correspond in type with certain of the Mousterian and Aurignacian tools of western Europe; they would appear to be of Middle Paleolithic age, variously estimated at from 40,000 to 200,000 years distant.

The habitation sites were marked by fireplaces and the presence around them of artifacts of stone, bone, shell, pottery, etc. These sites, of which traces were found in seven widely distributed localities, are characteristically confined to geologically ancient depressions in the Gobi topography, which have later been

fact that it is possible to interpret not the culture alone but also the physical environment of early man in the Gobi region. This is done through the careful correlation of geological processes and succession of events with the corresponding archeological observations.

Now I have given a brief appraisal of the major lines of investigation and accomplishment of the expeditions. Some of it has to be matter of fact. It is part of a catalogue of the discoveries of a group of men who gave their attention day after day in a matter-of-fact manner to scientific investigation in the

SUNSET AT TSAGAN NOR —*From the American Museum of Natural History*

CAMEL TRAIN CROSSING THE BELT OF SAND DUNES LYING BETWEEN THE LAKE, TSAGAN NOR, AND BAGA BOGDO OF THE ALTAI MOUNTAINS.

Desert of Gobi. This was their daily work and this other is their product and reward.

Many mere incidents of the journey, however, have left quite as lasting impressions on our minds. Never shall we be likely to forget the wild life, the great herds of antelope and of wild ass, the fierce wild dogs, and the sand grouse flying from nowhere to nowhere by the thousands every day. Neither shall we forget the simple poverty of the people, or the attractiveness of a fine lamasary with its group of temples and shrines and its hundreds of small huts to accommodate the resident lama priests. Some of these places are as impressive in their own setting and as great a contrast to the living quarters of the common people as are our own towering skyscrapers in the setting of New York. Nor is one likely to forget the old high priest who is probably still sitting where we found him that day chanting his Buddhist prayers with an earnestness that leaves no doubt whatever of the seriousness of religion in his life. One can still hear the call of the great trumpet and the rumble of hundreds of male voices joining in the daily chant in the service of Buddha.

One day after traversing a thousand miles of desert, we came to the borders of the Gobi, where the plain merges into the hill country of the Arctic Divide. Then after turning into a side valley we saw a mountain that at once claimed special attention. Its like we had not seen before in all Mongolia. Its simple, dignified outline, its long sharp crest, below which a black talus fringe fell like a drapery far down its furrowed sides, marked this mountain with a distinction.

We knew from our own experience, which by this time had given a working knowledge of the geology of the region, that this mountain must have a story of its own. So we were not greatly surprised at the reply of the high priest, a prince of the ruling house, a descendant of the Khans of earlier days, who dwelt there. "Yes," he said, "you may make a study of the spring and the mountain, but you must not kill anything, for this is holy ground."

Probably ever since people have lived in this region the mountain has been regarded with special veneration, not so much because of its distinguished appearance as because of the potential magic of the spot. Here hot waters issue from the ground. These are the healing waters of Sain Noin. If one bathes in them, he is cured of his ills. It must be that they have magical properties, and it may be that they bear to the surface at this singular place something of the supernatural that belongs to that other world beneath. It is a holy spot, and this impressive mountain, overlooking it as if guarding the place, is the Sacred Mountain of Sain Noin.

Here I suppose tribes have gathered ever since the beginning, at first with a feeling of awe, ultimately in reverence and worship, the ceremonies changing with the shifting of peoples, the advent of new religions, the lapse of time, and the varying imagination and spiritual insight of the priest who led them.

When we were all through, the map made, the sample of water secured, the reasons for the whole combination of unusual features worked out, and the time had come to make adieus to our priestly host, we thanked him for his assistance, and assured him of our great interest in the local phenomena.

Then he said, "Have you had a bath?" I had not, and when he indicated that he wanted me to bathe in these healing waters I realized that it must be a ceremony. So I agreed at once and he led me to the spot where several springs issued, and said, "This is your bath and this other is mine."

CAMEL TRAIN CROSSING THE BELT OF SAND DUNES LYING BETWEEN THE LAKE, TSAGAN NOR, AND BAGA BOGDO OF THE ALTAI MOUNTAINS.

There under a blue Mongol tent I found the granite rock hollowed out, with stones lying around the edge and waters as hot as one could bear issuing from the crevices in the bottom of the bowl.

Of course one ought to reciprocate, so we said to him, "You have given us what we have asked of you, now we are about to turn back. Within an hour we shall break camp and be on our way. By and by we hope to reach our own country on the opposite side of the earth. Is there anything you would like us to send you?" Then I got one of the shocks of my life, for he replied, "Yes, I would like you to send me an analysis of the water."

For a moment it took my breath away, but upon reflection it was not so surprising. Don't you see that we had discovered in this high priest of Buddha the elements of a scientific mind? If he had been born in America he would have been a scientist, and on the other hand if I had been born in Mongolia I suppose I would have become a Buddhist priest. Thus far apart are the opportunities of the two countries—as far almost in that respect as they are in physical position on the face of the earth.

THE GUARDIAN OF THE SACRED MOUNTAIN

THE PRINCE OF SAIN NOIN, A HIGH PRIEST OF BUDDHA, STANDING BEFORE THE DOOR OF THE ROYAL YURT, WITH HIS ATTENDANTS. IT IS A BREACH OF ETIQUETTE NOT TO ENTER BY THE GATEWAY IN THE STONE WALL.

THE VIBRATO IN CELEBRATED VOICES

By Dr. MILTON METFESSEL

THE STATE UNIVERSITY OF IOWA

I

RUBINI, the Italian tenor, is generally credited with introducing the vibrato into artistic singing in the early part of the last century. From then until now there has been a controversy among voice teachers as to the merits of a pulsating voice, with all the shades from approval to otherwise. There are those who denounce any vocal quivering whatsoever as inartistic, while others compromise in maintaining that pulsings are not jarring in passages where a trembling voice would naturally express strong emotion. A third group distinguish between the vibrato and tremolo, ascribing beauty to the former and ugliness to the latter.

Five years ago, when an experimental study of the vibrato was begun, it was evident that an attempt to throw any light on these differences would necessitate a new attack. Accordingly it was decided to leave out any possibility of personal equations, and to resort solely to mechanical devices.

Since then cameras for photographing sound waves coming from the vocal cords have been perfected to a high degree of accuracy. A voice photograph gives a more accurate and detailed description than is possible with the best unaided ear. The vocal cord vibrations are magnified a thousand times on moving-picture film in order to produce a picture large enough to study each individual wave, whereas the ear does not lend itself to such minute analysis, grasping only gross effects.

By measuring each wave-length on the photograph, any periodic variations in the voice however subtle, will be objectively ferreted out and notated. If there is a vibrato in a voice, the photograph will not only reveal it, but record it for measurement exactly as it is without partiality.

The voices of Caruso, Galli-Curci, Chaliapin, McCormack, Homer, and a score of other concert and operatic artists were photographed from phonograph records. What of the vibrato? Suffice it here to say that it was photographically detected in ninety-five per cent. of the tones. Any one playing a record of any recognized artist can verify the almost continual presence of this pulsation. If it is not immediately evident, the record may be slowed down until it becomes definitely perceptible.

Because it is so universal in artistic singing, it is fairly safe to hold that the vibrato has been tried and found beautiful. The occupants of the seats at the Metropolitan sit in collective judgment on whether a voice is beautiful or not. No matter how enthusiastic the "discoverer," his protégé must have a public. That public is ever ready to pick out the least flaw. Out of the many factors making for beauty, the absence of any one of them may destroy the effect of all the rest. It can not be just happenstance that vibratos are not only admitted, but required, in opera.

II

Measures of the sound waves of nearly three thousand vibrato cycles of recognized artists justify the statement that a vibrato to be desirable must have certain properties in just the right balance. Two of the most important properties are rate of pulsing, and extent, or the amount it rises and falls on the scale.

These properties vary within certain narrow limits without upsetting the equilibrium. Caruso sang one tone with a vibrato quivering eight times per second with an extent of a quarter-step, and the next tone surprisingly jumped to three-quarters of a step and six pulses per second. Such extremes actually are rare. Most rates cluster around the average of seven. His extent has a range from one tenth to a little over a whole-step, with the majority of extents occurring in the neighborhood of a half-step.

It is an interesting speculation that if Caruso had had a vibrato with an average of only six pulses per second—and this is the case of many music students—he would never have been an operatic star. None of the operatic artists studied averages as low as six. They all have about the same range of rate and extent as Caruso. This close correspondence of vibrato cycles of those who reach the heights is significant, representing a condition that seemingly must be met by the vocally ambitious.

From the sound wave analysis it would appear that anything so disjointed as a seven per second fluctuation of a half-step would be anything but beautiful—a violent auditory confusion. How can an artist whose voice shakes to such an extent sing in tune, to say nothing of following any standardized scale?

The answer—and here experimentation with ears is necessary—is that these changes are not heard *per se* in ordinary musical perception. A tone is generally grasped as a whole in consciousness, a phenomenon technically known as a *gestalt*. The hundreds of sound waves crowding in upon the ear of one enjoying music are given their own way, and they pile up on one another in the hearing process. A vibrato at a rate of seven times per second and an extent of a half-step is not a rise and fall of pitch in such a situation.

The variations fuse and produce an effect that is beautiful and unique. The tonal mass has one salient pitch at its focus, surrounded by a halo of tone-coloring peculiar to fast fluctuations. That salient pitch is generally close to mid-way between the extremes on the scale reached by the actual sound waves. For instance, one of Caruso's tones, measured on the sound waves, has a vibrato with a crest at C sharp and a trough at B, but on testing for the pitch heard, it is found to be approximately C with most observers.

It may be laid down that as long as fluctuations in a tone fuse into a steady predominant pitch, those fluctuations will be acceptable. Behind this statement are experiments in the laboratory in which conditions are so controlled that the balance of properties in the vibrato is broken down by one means or another. For instance, if the rate is too slow the fusion is lost, for there appears a continual shuttling of two notes. Observers complain that it becomes as disconcerting as hearing the same section of a melody over and over.

III

Having found that the vibrato is an integral part of artistic singing, and that to be beautiful it must have properties which are present in correct balance, resulting in a unitary pitch set in a variety of tone-colorings, it remained to see if there were any possible explanations for the radical differences of opinion.

An English musician-writer, who found part of his joy in life in railing against vocal pulsations, had his voice graphically recorded in Professor Scripture's laboratory in London. The professor kindly showed these records to the writer, and even a die-hard denouncer would have to admit the presence of the vibrato. The English musician is typical of a large group who talk about the

vibrato, but who have never analyzed their own voices for it. They are content to apply that title only to those pulsations which beat upon them violently, excluding all those of lesser insistence, similar in every other respect.

A hunter of cold facts is not surprised to find that a vibrato is an integral part of artistic singing, until he reads the musical literature. An American musician recently wrote that it is merely an assumption that all artists have the vibrato nearly all the time. This state of affairs suggests the necessity of setting up a series of control experiments to find out just what the situation is when a vibrato is not heard in artists' voices.

It was not difficult to find observers. One of them could not discriminate pitches a half-step apart. To such a crude aural mechanism the vibrato would be as perceptible as sights behind one's head. The others, however, had fair to middling pitch discrimination, but found it difficult to analyze a tone. It became evident that they were judging the vibrato not as tone fluctuation but as tone quality. Voice teachers have accounted for good tone quality in terms of resonance in the cavities of the head, but here was a tone quality which was due to variations in the tenseness of the vocal cords.

The psychological principle that fast variations in a train of sound waves may fuse in perception and are then interpreted as tone quality, was determined by the simple expedient of sounding different vibrato cycles from the time-honored laboratory siren. If dissimilar vibrato cycles were sounded, the observers reported that the tones were different in quality (timbre), yet actually the forms of the sound waves—upon which quality theoretically depends—were precisely the same. At first these observers could not analyze a vibrato out of a tone, but after training they all became proficient. It was a question of substituting one habit of hearing for another.

Paradoxically, it is just as great a sin to analyze a vibrato as not to analyze it. Trying to hear the actual half-step limits of a vibrato is fatal to beauty. It is getting up too close. What in a masterpiece viewed at a distance fuses into a beautiful effect, upon close inspection becomes tawdry daubs. Dissecting the vibrato into its two pitch limits destroys the auditory fusion. A certain way to have a disagreeable evening at a concert is to listen for a vibrato. When it is subjectively jerked out of its proper place in the background, it is an entirely different piece of mental furniture.

To analyze or not to analyze—when? When discussing the vibrato, or studying it, it is necessary to know what is being talked about. When enjoying a voice, ignorance is bliss. The further the vibrato is auditorially submerged, the better.

The vibrato analyzers are of two groups. The one trains himself to hear a vibrato only when he wills it, while the other can not help hearing it. A compliment for the extinguishers! Because of fine sensitivity and keenness of their ears, some hear the vibrato as a shaking just as surely as they can detect the slightest sharping or flatting. Fusion for them is more difficult than with a less accurate ear. Possibly this accounts for the attitude of Meyerbeer, Auber and Gounod. But the sensitive ear is rare, and so a vibrato heard as a wobble is rare.

FIG. 1. CHRISTIAAN HUYGENS, BORN APRIL 14, 1629.

CHRISTIAAN HUYGENS—(1629-1695)

By Professor FLORIAN CAJORI
UNIVERSITY OF CALIFORNIA

THE year 1929 brings the three hundredth anniversary of the birth of Christiaan Huygens, of Holland, one of the greatest mathematicians, physicists and astronomers of the seventeenth century. His father, being a poet and statesman, marked out for him a literary and diplomatic career, but his early love for the exact sciences overruled that decision. Endowed with great imagination, great mathematical power and with a penetration and freshness of intellect which abided to the end of his life, Huygens contributed not only views fundamental in the philosophy of science, but also inventions of importance in everyday life. His earliest publications were mathematical in character—the determination of the area of a figure with the aid of its center of gravity, the theory of probability and the invalidity of certain pretended quadratures of the circle. Debates on the latter topic made him widely known, though he was still very young.

He perceived that observational astronomy needed for its advancement better telescopes and better clocks. He succeeded in improving both. Working with his brother Constantijn, he, in 1655, devised a superior method of grinding and polishing lenses. With a new telescope of improved definition, he discovered a satellite of Saturn, now known as Titan, the sixth Saturnian moon in order of distance. In the same year he made a second important discovery, namely, the determination of the true form of the abnormal appendages of Saturn. Galileo, to his amazement, had seen Saturn through his imperfect telescope "threefold." Hevelius saw it in three parts. Fontana made drawings of Saturn widely distorted. Modern students have little idea of the observational difficulty encountered by seventeenth century astronomers working with telescopes exhibiting distorted, colored and blurred images. The age of the achromatic lens had not yet arrived. The subtilty of the puzzle was enhanced by the change in appearance of Saturn when viewed from different relative positions of Saturn and the earth, as they revolved in their orbits. In 1655, Huygens drew Saturn as a sphere with two handles or arms on opposite sides and extending in opposite directions. When Saturn was near the sun, in January, 1656, the arms disappeared. The manuscripts of Huygens contain scores of drawings of the planet as seen at different times. He noticed a periodicity in the shapes which Saturn assumed. His constructive imagination supplied him with what seemed to him the correct explanation. To secure priority of discovery and yet allow him time for full verification, he made an announcement under the veil of an anagram, and not till four years later did he publicly explain his anagram. In a letter (August, 1656) to Roberval, he drew three Saturnian forms, shown in Fig. 2. His anagram was a Latin sentence which in translation is: "It is surrounded by a slender flat ring, everywhere distant from the surface, and inclined to the ecliptic." Thus the "handles" were recognized to be an encircling ring. Huygens entered upon the improvement of telescopes again, a quarter of a century later, and he developed the so-called "Huygenian" type. The magni-

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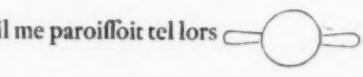
oppoſees deux a deux, il confeſſe de l'ignorer et d'eſtre deſireux de l'apprendre, en quoy je puis luy ſatiſfaire, et l'aurois deſia fait ſi d'autres choſes ne m'en avoit diverty.

Voſtre hypotheſe pour Saturne eſt certainement treſbien imaginée, et n'ayant point d'autres phaenomenes a concilier ny d'obſervations plus exactes, vous ne pouviez pas peut eſtre mieux rencontrer. Je m'eſtonne toutefois que vous ne faites aucune reflexion ſur le temps periodique de toutes les diverſes apparitions de Saturne, qui reviennent touſjours ſucceſſivement et deux fois en 30 ans. Si les anſes eſtoyent produites d'une exhalaiſon, il n'y a pas beaucoup d'apparence qu'elles renaiſtroient ſi preciſement a des certains temps, et le quiteroyent de meſme. la forme ovale que du commencement quelques uns ont obſervée a eſté cauſee de l'imperfection des lunettes dont ils ſe ſont ſervy. autrement le corps du milieu de ce planete paroit touſjours rond a fort peu pres. Cette année je l'ay veu touſjours de cette forme

l'année precedente il me paroiſſoit tel lors  , que tous les autres obſervateurs la voyent ainſi ○◯○ : mais avec des lunettes qui ne leur decouvroit pas le nouveau ſatellite, d'ou il s'enſuit que les mienes eſtoient meilleures.

Monſieur Hevelius m'a envoyè dernierement &c.

FIG. 2. FROM A LETTER OF HUYGENS TO ROBERVAL (AUGUST, 1656), CONTAINING DRAWINGS OF SATURN AND ITS RING, AS SEEN BY HUYGENS AND OTHERS.

fying power is measured by the focal length of the object glass, divided by the focal length of the eye-piece. Huygens and his brother Constantijn increased the magnifying power by enormously increasing the focal length of the objective. He presented to the Royal Society of London three lenses having focal lengths of 123, 170, 210 feet, respectively. It being impractical to construct tubes of such great length, Huygens discarded their use and adopted for nocturnal observation the "aerial" telescope (Fig. 3); the objective was mounted on a high pole and set in line with the eye-piece by means of a cord, but it was found difficult to get the eye and object glasses *married* or brought parallel to each other. Huygens promoted accurate observation also by the invention of the micrometer, and of the pendulum clock (an honor which he must share with Galileo). See Fig. 4, I. He worked out the mechanics of the pendulum in that wonderful book, the "Horologium oscillatorium," written in 1665 and first printed in 1673. On June 16, 1657, he presented a pendulum clock to the states-general. He suggested a pendulum vibrating seconds as a unit of length. As the ordinary pendulum vibrates somewhat faster when swinging through a smaller arc, Huygens developed the cycloidal pendulum (Fig. 4, II) which is theoretically free from that defect, but proved to be incapable of accurate construction. This pendulum is perfectly isochronous. Its point of suspension coincides with the point where the two cycloidal jaws meet, and the suspending thread touches the jaws so as to be tangent to them. The effective length of the swinging pendulum is the distance of its center of oscillation, not from the point of suspension, but from the point of tangency. Thus the vibrating pendulum has varying effective lengths. It is shortest at the

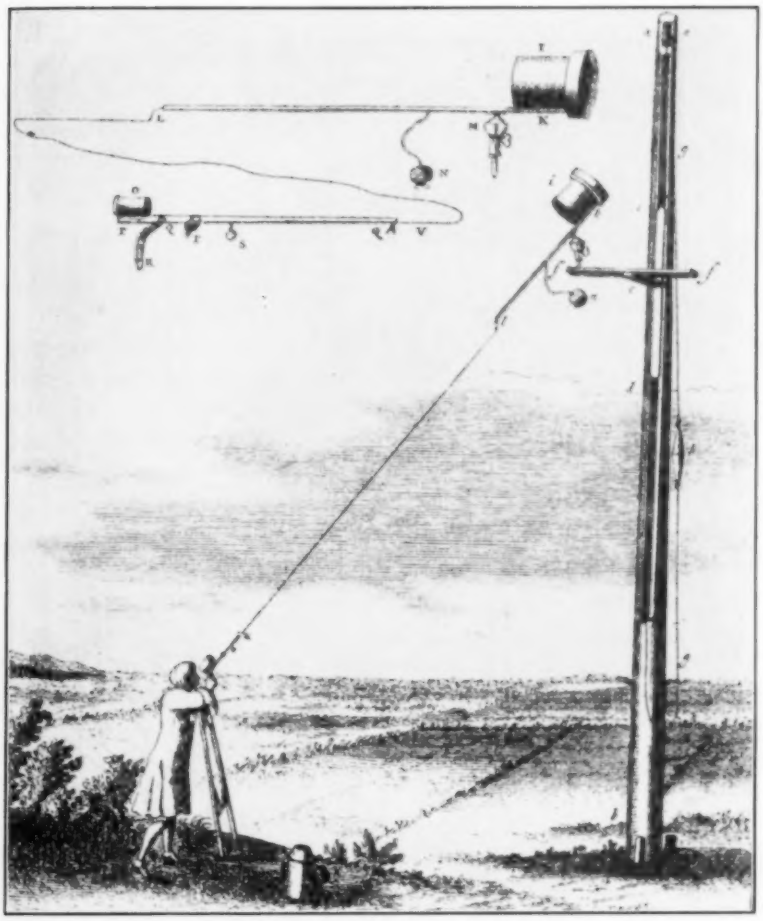


FIG. 3. HUYGENS' "AERIAL" TELESCOPE

extreme ends of its swing, and longest in its vertical position. These changes in length due to the cycloidal arcs are exactly what is needed for isochronism. Huygens invented for the practical needs of mankind the spiral watch-spring.

His astronomical observations, his improvements in time measurements, and mathematical publications gave him a wide reputation. He visited France and England in 1660, and again in 1663, when he was elected member of the Royal Society of London. That society invited attention to the investigation of the laws of impact, and received complete solutions from Huygens and also from Wallis and Wren. Thus was established the third law of motion, previously not fully understood. Huygens worked out the mechanics of circular motion and of centrifugal action. Newton was greatly assisted by these important results and spoke of Huygens in terms of highest admiration.

When Colbert, the far-sighted minister of finance of Louis XIV, invited Huygens to Paris to become member of the newly organized French Academy of Sciences, he accepted, and retained this

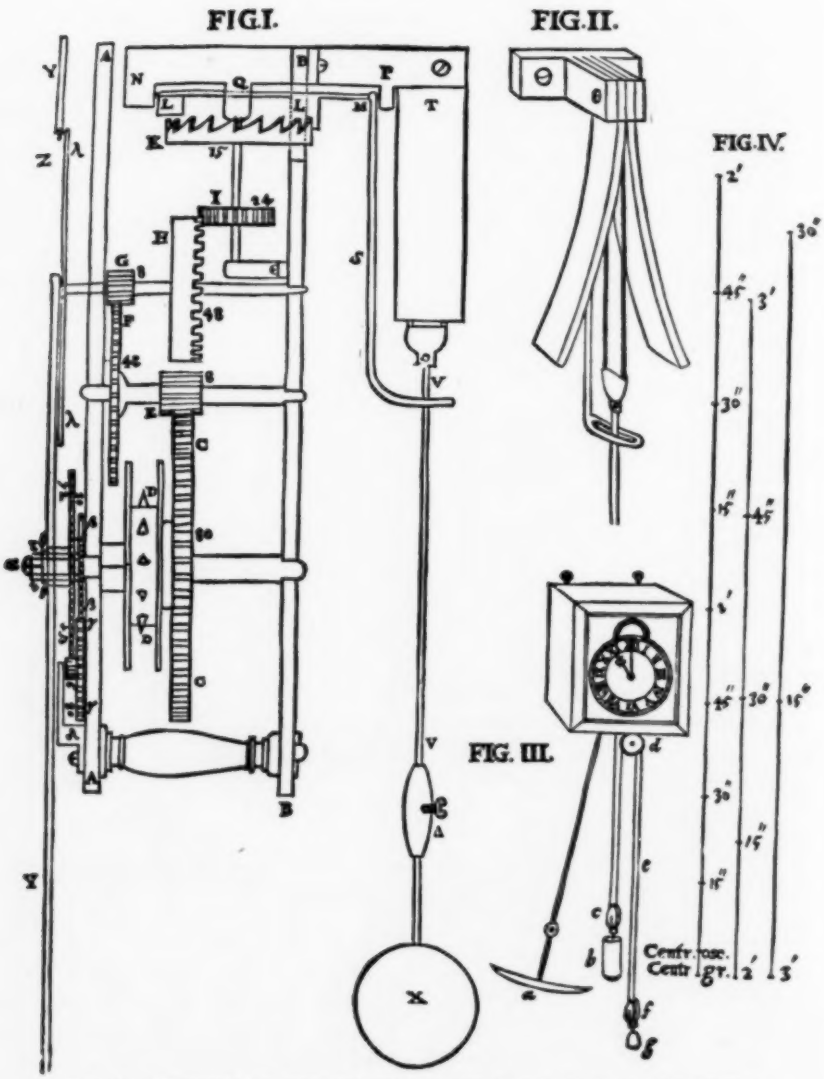


FIG. 4. HUYGENS' PENDULUM CLOCK, AND THE CYCLOIDAL PENDULUM.

honorable position from 1666 to 1681, when he returned to his native country. His return is said to have been due, in part, to ill health, and in part to the edicts against the Protestants. It was in 1678 that he advanced the great "wave theory of light" and postulated the existence of a luminiferous ether. This research was not printed until 1690. Such a theory had been suggested by Robert Hooke, but Huygens developed it more fully, explained the motion of a wave by the formation of partial waves at all points of the wave front ("the Huygens principle") and found an explanation for the reflection and refraction of light. However, Huygens did not clearly set forth the phenomenon of interference; that was done later by Young and Fresnel. It is

well known that Newton advanced a rival theory of light, the "emission theory," which in the eighteenth century superseded the wave theory, but which in the nineteenth century was itself superseded by the wave theory. In the present century both theories are coming to the front, no longer as rivals, but, apparently, under the more general view-point of "wave mechanics."

The mind of Huygens remained receptive to new ideas to the last. When Newton's "Principia" appeared in 1687, he examined it minutely and fully accepted Newton's explanation of planetary motion. He had been an adherent of Descartes's theory of vortices, but he was probably the earliest continental scientist to abandon Descartes and publish adherence to Newton's celestial mechanics. However, he did not accept Newton's view that gravitation was a property of matter and in that respect he, and Descartes before him, indulged in speculations that were almost uncanny. In this negation they anticipated Einstein. Huygens endeavored to explain the cause of gravity, in which he failed, as did Newton and every one else. A posthumous publication of Huygens, the "Cosmotheoros," indicates that he had indulged in another speculation which has become of great interest to the twentieth century public, namely, the question concerning inhabitants of the planets. Richard A. Proctor tells us that, as an expression of the pleasure derived from reading this book, Dr. Thomas Plume in England founded the Plumian professorship of astronomy at the University of Cambridge.

PHYSICS IN INDUSTRY AS A CAREER

By Dr. ROBERT W. KING
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THERE is a world of difference between *physics* in industry and *physicists* in industry. After a physicist gets into industry, his career often ceases to be in physics. It is in a sense axiomatic, and yet it will bear frequent repetition, that industry tends to distribute its men in such a way that each individual can make his most valuable contribution. In the case of the physicist, this frequently turns out to be in some field divorced from research but in one, of course, in which his training and knowledge of physics are of conspicuous value.

In a very real sense every industry is a biological experiment. Like the microscopist who is extracting protoplasm from a cell or juggling its chromosomes, also is the industrial magnate who is putting into practice his schemes of organization and division of labor studying biological principles. In one case, the organism under investigation is a single cell, perhaps a tenth of a millimeter in diameter. In the other case, it is an organism which may comprise tens of thousands of human beings, each of whom is one of its biological units; and the organism as a whole may extend throughout the nation or even be of international scope.

Internally the fundamental problem of each business is to build up an employee body, the members of which are so chosen for talent and training in their respective fields that they will cope with the problems of industry as a single individual whose mind embraces all pertinent knowledge. In the large industrial organization the research

laboratory, of course, plays an important part. Industrial research problems are so broad to-day as to call for the collaboration of experts in many lines, and the large laboratories developed to cope with these problems not infrequently include physicists, chemists, electrical and mechanical engineers, mathematicians and design experts. The members of such a staff constitute more than the proverbial happy family. Intellectually they are the brain cells of a "super-organic" being.

To illustrate the cooperative effort of such a corps, consider the development of the machines that establish central office connections in the dial telephone system. To one who has had no association with this apparatus it is quite impossible to picture its complexities. A simple machine-switching connection requires the making and breaking of some 1,400 relay contacts, and a single circuit would take a blackboard of a good-sized classroom for its delineation. The work of designing the circuits has of course been divided among many men and the design of the apparatus among many more.

Nor have contributions to the system been confined to electrical and mechanical experts. The mathematician, for example, has been indispensable. Dial telephone apparatus is expensive, and is therefore so designed and installed as to handle the maximum number of calls. Thus the load-carrying capacity of each piece of equipment through which a call in turn passes must be proportioned to the time interval during which the call keeps that piece busy. Likewise, in determining the proper amount to install in a central office many intricate problems in the theory of probabilities arise to which a small corps of mathematicians give most of their time.

And to the ensemble of solutions, the physicist has contributed his share, for example, in the design of a wide variety of slow- and quick-acting relays. Some of these are given the lightest of moving parts while others are supplied with heavy copper collars in which eddy currents impart just the proper degree of sluggishness of operation. The wise choice of magnetic materials and the development of new magnetic alloys have also played their part. For one man to have solved all the problems which the development of the dial telephone system has involved would have required not one but many lifetimes.

It is unnecessary to contrast in detail this manner of working with that of university research workers to show how different the two are. Let us pass on instead to a fuller inspection of research in industry.

This will disclose the real difference between pure and applied research, and —in a measure—the origin of considerations concerning patents and corporation policy affecting publication by its employees. We shall also understand the need of that quality for which all industries are ready to pay the highest rewards, namely the talent for organizing and guiding the efforts of others. There are, moreover, the rules of industrial research arising from its basic economic and commercial aspects. This in turn has a direct bearing upon the matter of initiative and the opportunity for individual freedom in choice of problems in industrial research.

The French physicist Biot once declared of the scientists of his period that their science was not the more apparent for their want of literary culture. We might paraphrase this by saying of present-day science that it need not be the less apparent when associated with industry. The mental attitude of the research worker in industry should be no different from that of his academic confrère. In general, it would be fatal

to the success of industrial research if those who are responsible for its management were guided by any other motive than a search for all the information that their skill is capable of bringing to light. Every one who has had experience in industrial research can call to mind cases that illustrate this point—cases where certain avenues were not followed because they seemed of less promise from the standpoint of useful application, only to have certain aspects of the art change shortly thereafter, so that the investigation which was abandoned in favor of another would actually have been the more valuable.

As an intellectual pursuit there need be no doubt in any one's mind but that applied research is the peer of pure research. They must necessarily deal with the same facts of nature in the same way; the same appliances for investigation and the same logical processes are employed in each. They overlap in subject-matter, and—with a frequency that is now taken largely as a matter of course—the frontiers of our knowledge are pushed forward by the discoveries of the industrial scientist. There is, however, a single fundamental difference between these two fields of endeavor. It is, as I have intimated, a difference of motive. The incentive behind pure research is the joy of discovery; the incentive behind applied research is to harness one or another of nature's forces and apply it to man's needs.

While this statement is broadly true, it does not of course follow that every one engaged in industrial research is working upon the frontiers of our knowledge. A research organization of which this could be said would not be a balanced body of workers from the industrial point of view. Actually the number engaged in advancing scientific outposts is necessarily much smaller than the number devoting their time to practical applications. There is also the chance that the status of the individual worker will shift from the field of investigation to the field of application.

Since the motive behind applied research is that of advancing an industry, the decision to make disclosures and to publish the results of investigations can be made only after proper protection has been obtained. Fundamental to all publication is the work of the patent solicitor, who must first satisfy himself that the competitive interests of the industry are being protected. Publication in advance of the filing of patent applications nullifies these and allows the world generally to profit equally with the industry itself by the results.

It seems to be the general policy in industrial laboratories to place the protection not upon the research staff, but upon a special group of patent attorneys whose business is to keep themselves well informed regarding all developments and progress. Naturally they try to do their work so expeditiously that little delay intervenes between the completion of a research program and the publication of its findings.

It might be remarked parenthetically that we have here an instance of pure science borrowing from the methods of applied science, a phenomenon which has been rare in the past but is likely to occur more frequently, for some of the methods of applied science have much to commend them. Some of our universities now maintain on their staffs a patent expert to keep in touch with the programs of faculty research and apply for suitable patent protection, to the end that whatever of practical value the patents may have will return to the institution to augment its funds for investigation.

There are other figurative elbows, the rubbing of which makes the physicist in

industry realize that he is not so much an individual as a member of an organization. Academic research, individually conceived and conducted with little or no assistance from satellitic graduate students, presents a strong contrast to the research method of industry. The university research worker generally considers—and the world is quite willing to agree with him—that he is working on his own time. Unfortunately there is little interest on the part of society as to whether he is spending his time as usefully as possible. Under these circumstances it is natural to find him constructing and adjusting all of his data, even though these might be performed as well by some one of considerably less research ability. Perhaps it would not be wide of the mark to estimate that the average academic research worker gives half of his time to jobs which might be safely entrusted to assistants were the arrangements such that satisfactory help could be hired.

The practice in industry is naturally very different. To the business world research is distinctly a money-making or money-saving matter. When industry hires a physicist it expects him to follow his profession throughout the working day, and to spend as little as possible of his time on the kind of jobs our graduate students have so appropriately dubbed "plumbing." If his work is of such a character that any of it can be delegated to those occupying less favored positions on the payroll he is expected to avail himself of their services. Indeed, so far as his advancement is concerned, it may count somewhat against him if he does not, or shows that he can not, so organize his work as to avail himself of the services of others. The industrial physicist in a sense constitutes the higher brain cells of a group of workers who look to him for their guidance in such matters as lie beyond their knowledge. He must supervise the planning and thinking of the group reporting to him, and to the best of his ability focus their efforts upon the problem which he has in hand.

At this point it is natural to ask how the physicist and the group under him come into possession of their problems. It goes almost without saying that the majority of the staff of an industrial laboratory must be working on problems whose outcome, if successful, will be applicable in important ways to the commercial activities of the industry. This of course implies that all research work in progress has the sanction of those executives who in the end will be held responsible for its outcome. It is not possible, however, to give any rule as to the origin of individual problems and even larger research programs. These may arise as a natural outgrowth of changing commercial conditions or they may represent a forecast of future requirements made anywhere up or down the line of organization, but undertaken of course with the approval of those higher up. It is not far of the mark, however, to say that the physicist in industry may at times prove as valuable for his suggestions regarding promising fields of investigation as for his skill in unraveling an answer once the problem has been agreed upon.

In the prosecution of his investigations the scientist in industry should not and does not ordinarily feel overconstrained. On this point I might quote from Dr. H. D. Arnold, director of research of the Bell Telephone Laboratories:

> To attempt to order in advance the detailed conduct of a problem would be undesirable and futile and would indeed violate the very spirit of research, which is one of self-reliant adventure along uncharted paths. Any proposal to limit too closely the initiative of the experimenter is bad, and its adoption would be certain to impose upon results the fallacies inher-

ent in prejudgment. Nevertheless, a broad and careful consideration must be given to each research at its inception, for the course of experimentation is long and costly and not to be lightly attempted.

Life in an industrial laboratory may in a sense be compared to life on a military front where the scene of active fighting swings to and fro. At any moment the order may be given to advance against some unknown sector. There may be some definite time-element involved. There will probably be numerous conferences with other laboratory groups, so that all information becomes common information. Progress may prove fast or slow, but the experience has its thrills which are in no way lessened by the practical importance attached to the outcome. After months or sometimes even years of strenuous work, one department, upon the completion of an active program, may settle back into comparative calm, frequently leaving to those who were but recently straining every nerve sufficient leisure to plan attacks upon lateral problems uncovered in the course of the work and which for one reason or another seem worthy of further study.

This brief consideration of the industrial scientist's relation to his problem forms a logical point of departure for a consideration of his relation to the organization of which he is a part. The necessary collaboration can be fully realized only through conscious and willing effort on the part of each member of the staff. The executives do not, of course, effect the collaboration; they can do little more than indicate its proper channels. The individual himself is primarily responsible for harmonizing his work and also his manner of working with that of his associates. The industrial worker is naturally immersed in an atmosphere of teamwork, and he is expected to make such contributions to the general program as the division of labor has assigned to him and his staff.

To most people the cooperative spirit that pervades industrial work is quite enjoyable. There are a few features, however, which may at times call for a philosophical attitude. Thus, after a development problem has been divided among several experts and each has made his contribution, it frequently does not prove practicable to publish a paper or papers bearing the names of all the collaborators, and some who have made important contributions may remain unnamed. In such a case the individual naturally does not have his contributions recognized at once by the world at large. But he can comfort himself with the thought that at least his superiors—and the payroll department—are not likely to be ignorant of what he has done.

Doubtless the physicist in industry is more remuneratively rewarded than his brother in the university. Among the reasons which may be ascribed to account for this condition, one factor, and to the speaker's mind an important one, is so seldom alluded to that it will be discussed here. It is a natural consequence of the cooperative effort which characterizes industrial research that a single individual may make contributions much more valuable than any which he could make if a lone worker. A hand or ear or eye by itself would not be much sought after—outside a medical college—but when these are integral parts of a Faraday or a Kelvin it may be worth society's while to bid quite high for them. Briefly, what those industries are doing which are engaged in scientific work is building composite Faradays and Kelvins whose breadth of understanding is approached by no single person and who are eminently competent to cope with the tremendously complex problems that industry gives rise to.

I do not wish to imply that an organization man is always more strategically situated than the detached person in respect to the value of the contribution which he can make to society. It is easy to cite the cases of celebrated lawyers, doctors and engineers upon whose individual contributions the work has stamped large pragmatic values. This means that the opportunity does arise in which the gifted individual can accomplish important things single-handed. But such cases in no wise tend to disprove the thesis that the more closely the efforts of the average worker tie in with those of others the more valuable do his efforts become.

An illustration chosen from the domain of physics may be of interest. The amplifying device known as the telephone repeater is becoming of greater and greater importance in our plant because of the increasing demand for long distance facilities. The familiar three-electrode vacuum tube forms the amplifying agent of the repeater. For telephone work we have always employed an oxide-coated filament, because it has reduced what we might term the "cost of electrons" well below that obtainable with any other known type of filament. We were not satisfied, however, with the oxide filament because it was the best then known. There seemed reasons for believing that it might be further improved. Ten years ago the repeater tube consumed over five watts in the filament and had an average life of 1,000 hours. This is very satisfactory considering even the best radio tubes of to-day. To-day, however, the telephone repeater tube consumes two watts in the filament and has an average life well over 25,000 hours, and yet gives as abundant a supply of electrons as its predecessor. Translating this investigation in the field of thermionics into money shows a saving to the telephone business of this country of about five million dollars a year.

The filament investigation can be used to illustrate other outstanding characteristics of industrial research. As just stated, the study of filament coating extended over a period of ten years. It would be hard to say how many persons participated in it, or how many thousands of tubes were made and studied during this time, but the cost of the program averaged somewhere in the neighborhood of $200,000 a year, so that its total cost was about two million dollars. This program was launched and funds authorized by the executives years before there was any basis for definitely foreseeing a successful outcome.

It would be difficult to conceive of such a change in the conditions surrounding academic research that a program of this kind could be carried out under university auspices. Nor is there any reason why it should be so conducted. The investigations were not particularly fruitful from the standpoint of new principles uncovered. There was little of the kind of work in them that we find described in the leading journals of physics. Of course, new principles might have been uncovered or some striking new discovery might have been made. This, however, was not the purpose of the investigation, and no one feels that it in any sense failed or miscarried because such an outcome was not realized.

The enormous value of specific research jobs to industry naturally leads us back again to the scale of compensation upon which industry rewards the individual scientist or the small group whose contribution proves to be measurable in millions of dollars. On this point I can speak with complete assurance only for the business with which I am best acquainted. Those of you who read the advertisements of the Telephone Company know that it claims to have made no millionaires. This in part answers the question. The men who developed the vacuum tube filament just

referred to did not profit to the extent of several millions, nor would any one seriously maintain—least of all themselves—that their reward should have been commensurate with the value of their contribution. This would have involved unjustifiable exploitation of the telephone-using public. The millions upon millions of dollars which scientific research, as carried on within this industry, has saved belong rightly to the public, and are being returned to them, partly in the form of better and more extended service and partly as reduced rates. This I believe to be the attitude which industries in general adopt toward the public which supports them.

In a sense, of course, salaries like everything else in the business world are determined by the law of supply and demand. However, no direct appeal is made to this law in establishing salary levels. One thing that industry is trying more and more to protect itself from is labor turnover, and nowhere is this policy of greater importance than in the administration of a scientific staff. The result is that, in general, such staffs are well paid and supplied with stimulating working conditions.

Scientific research both pure and applied have never flourished as they do to-day. Applied research stands nearer the coffers and treasuries, and in the matter of money for salaries and equipment occupies the favored position. For this reason, together with the fact that it has proved a most successful money-making venture, its growth has perhaps been accelerated beyond that of its companion. This situation is viewed with apprehension by some who have the interests of pure science closely at heart. I believe we may affirm, however, that the opposite and optimistic view is the correct one. Although applied science draws its money from industrial treasuries, it draws what we might call the vitamin ingredients of its diet from pure science, and the economic forces which are propelling industrial research at its present prodigious rate must in turn insure that the source of its prodigy's life-giving elements does not languish. An important movement to this end with which the names of the National Research Council and the National Academy are associated is already under way. This may well be the nucleus of a nationwide mechanism suitable for transmitting to pure science the contributions of an appreciative commercial world. Several of our leading industries have already recognized their indebtedness to pure science by large contributions to the National Academy fund. Are we not on the threshold of a new era when our universities and industry will walk shoulder to shoulder, looking upon each other as equally important participants in the world's greatest undertaking?

OCEAN PLANKTON AND PLANKTON PROBLEMS

By Professor WINFRED EMORY ALLEN

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Definition of Plankton

Plankton is a vague term invented by Hensen in 1887 to include for convenience in discussion all organisms suspended in sea water without powers of changing locality by the efforts of individual components. The original definition emphasized flotation, and the most common usage at present follows this line of emphasis with supplementary qualification by expressions such as "weakly swimming" and "passively floating." As a matter of fact this emphasis on flotation and passivity is likely to convey a wrong idea as to the characteristics necessary to include an organism under the convenient heading which is intended to cover all of those not sedentary on the one hand and not actually or potentially migratory or itinerant on the other hand.

Indeed, it is readily apparent to any one familiar with plankton that many zooplanktonts (*e.g.*, arrow worms) swim with power and speed exceeding that of most fishes. But their size is so small that they have to swim many times their own length to traverse a foot of water, and the utmost distance covered in a day could be passed in a few minutes by many fishes. Far removed from the arrow worms in almost all ways are the large jellyfishes which are much larger than most fishes (extending over ten or fifteen feet) but which can move their great bulk probably less distance in a day than an arrow worm can move itself. As regards passivity, perhaps diatoms furnish the best examples and the smallest size of planktonts may be found in the bacteria.

Amazing as these differences in the components of the plankton may be there are others just as great. In the cycles of marine life some planktonts are builders (synthesizing plants) and some destroyers (predatory animals). Some are hunters, others parasites and others scavengers. Some are innocuous to neighboring organisms, while others are poisonous or otherwise injurious. Some are temporary and some are permanent in plankton membership. Amongst temporary planktonts most kinds are planktonic in embryonic or immature stages, but some are planktonic only in mature stages. Most of the orders of plants below the Bryophytes are represented in the plankton in some way or other, and all of the phyla (branches) of the animal kingdom have some kind of representation in it.

In consideration of the broadly intricate relationships thus sketchily suggested it may be obvious that only two criteria can be applied in identification of plankton and that they are not capable of exact delimitation. These two criteria are free suspension in the water, and lack of capacity to control their locality of occupation.

If any one supposes that free suspension is a criterion which always can be applied precisely he need not go far to discover his delusion. I strongly doubt that any student of plankton is able to distinguish certain very early larval stages of whale barnacles from similar stages of many other crustaceans, some of which may belong to the permanent plankton. Still less do I believe that any one would be able to say that a larva ready for attachment to its whale host is clearly planktonic in character. It may be caught in his net because no whale host is within reach, but its real

character is that of a fixed parasite. Still more difficult would be the cases of some of the parasitic copepods and some of the parasitic worms, especially some of those less specialized, which might leave one host for another and be captured in transit. Similarly confusing are the cases in which one small organism fixes itself to a true plankton organism either temporarily or permanently. It is not freely suspended (or "free floating" as stated by some definitions). On the other hand it would be palpably absurd to ignore its presence in the plankton population.

"Lack of control of locality" is the term which I have adopted to cover the idea that "plankton" includes those organisms at the mercy of their inanimate environment, helpless to avoid aimless drifting in moving water or indefinite detention in still water. There are two major difficulties which may appear when attempting to apply this criterion: first, what extent of movement permits inclusion; second, how may it be known when development of an immature organism has carried it beyond this limit of inclusion?

Concerning the extent of movement it is pertinent to inquire if a rate of transit of one mile per hour would exclude an animal from the plankton group. Or should the limit be placed lower or higher? Furthermore, how is the distinguishing rate to be recognized? Should it be necessary for the distinguishing rate to be sustained for one hour, or for any other definite unit of time? Should any effort be made to distinguish random movement from movement apparently purposive?

Concerning the point of departure of a growing animal from plankton classification one may find his practical difficulties somewhat embarrassing. A number of very small fish may be taken in a plankton net and readily recognized as belonging to the plankton group. Another catch near by may include some as easily recognized as beyond that classification. Another may include some of intermediate character. How is one to determine the line of distinction?

For certain rare cases perhaps a third difficulty may appear to have major rank, *i.e.*, when an animal apparently capable of change of locality habitually associates with and seeks the protection of a plankton organism why should it be excluded from plankton classification? For example, there are the little fishes which shelter themselves amongst the stinging threads of the Portuguese man-of-war. By habit they appear to be planktonic, by capacity nektonic (capable of choosing locality by directive movement).

It is true that in practical investigations these difficulties may rarely or never appear obtrusive. But it is none the less true that they have a positive relation to the formation of an idea of plankton as a group of things and that they can not be entirely disregarded in comprehensive attention to plankton problems.

General Aspects of Plankton Relationships

Supposing that we hazard a guess that there are not more than one thousand species of permanent planktonts (successive generations maintaining a planktonic existence through the entire lives of the individuals composing each), and not more than ten thousand species of planktonts of all kinds and degrees, still we can not ignore the fact that any one of hundreds of these species may sometimes appear in clouds that render great areas of water "soupy" or gelatinous, and that each single organism bears n intricate series of relationships to others of its kind; to other planktonts; to other inhabitants of the sea; to the physical and chemical characteristics of the water, of the air, of the sea bottom, of the coast lines and of the land; to topography and geology of the region; and to

solar radiation and other astronomic influences. In other words, the fundamental problems of the plankton are not only profoundly intricate as concerns marine organisms but they are inseparable from many of the fundamental problems of oceanography in general and of cosmography.

While it is obvious that the ramifications of the threads of relationships involved in the solutions of these problems are beyond the limits of human capacity to trace in detail, it is also obvious from practical experience with problems of nature that certain figures or patterns formed by the intersections of these ramifications may be traced and the information applied in approximate solutions which serve the purpose of true solutions for ordinary needs.

Avenues of Approach to Plankton Problems

According to the needs or interests of the observer or investigator there are several different avenues of approach to plankton problems, involving more or less distinctly different statements of the problems and their elements, more or less distinctly different methods of solution and more or less distinctly different views as to the degree of approximation to a true solution which may be acceptable.

To a physical oceanographer problems of the plankton (or, indeed, any problems of marine biology) may appear to have only academic or theoretic interest or value. He may see readily enough that differences in abundance of organisms may cause differences in rate or direction of flow of certain limited masses of water, that accumulation of organisms or masses of organic remains may make significant alterations in contours of ocean basins, and that physical properties of sea water may vary under certain relationships to organisms, but he can not see that the influence of organisms is appreciable when compared with several other influences in practical operations. Therefore he rates biological phenomena as constituting a negligible factor which safely may be ignored in ordinary discussion of the oceanic mass as a whole. If attention be required for purposes of highly localized interpretations he can get along very well with exceedingly rough approximations. For example, his time units rarely need be smaller than millennia or his space units smaller than thousands of square miles or cubic miles. In most cases he does not need even to distinguish plants from animals in considering the organisms involved.

Up to a certain point the marine navigator shares the avenue of approach of a physical oceanographer, but at that point there is sharp departure when he finds that certain marine organisms are destructive to his shipping and his port equipment and that certain others are related to products valued for the opportunities they give for transportation and exploitation. So far as he is concerned the problems of the plankton are highly specific and definitely delimited. His primary interests are typically in certain temporary components of the plankton larval stages of ship worms and other borers, unattached stages of barnacles and other encrusting organisms, briefly, in those stages showing vulnerability to lethal agents or susceptibility to deterrents. But if he concludes that some other kinds of plankton organisms may yield, or help to yield, products of commercial value, he may exhibit primary interest in plankton distribution and in characteristics of plankton production and maintenance which may be directly or indirectly used for his advantage.

A commercial fisherman is likely to take no interest in plankton problems unless he can be convinced by some one that an acquaintance with plankton is necessary in order to develop and sustain the fisheries. Once convinced, his

interest may become active, but it is almost sure to be narrow. All he wishes to know is how any particular kind of plankton affects the particular kind of fish that he seeks or how his methods of fishing may be made more profitable by attention to plankton. All an oyster fisherman wants to know is what kind of plankton is used by the oyster for food and how this kind can be most effectively furnished to that mollusk. His main interest is in the possibilities of plankton culture for oyster food or in the methods of planting oysters which will give them best contact with such food. A sardine fisherman would be interested in studies which might show him how to use plankton indicators in hunting for that kind of fish, something similar to the color signs which he already uses to some extent, *e.g.*, yellow water and brown water. He would also be interested in plankton studies which might give him some clue as to whether a coming year would be favorable or unfavorable for catching these fish. Perhaps the studies which would appeal to him most strongly in some localities would be concerning what plankton animals prey upon larval sardines, to what extent their destructiveness affects the numbers of commercial size at any given period and to what extent preventive or remedial measures may be applied. But in all cases fishermen would be satisfied with broad statements of these problems and of the terms of their solution, and with rather crude studies of restricted groups of plankton.

Any geologist who pretends to an understanding of the structure and origin of enormous areas of the earth's surface to-day must give at least a little attention to plankton organisms of remote geologic time. If his work is purely descriptive or narrowly restricted to a particular type of structure (*e.g.*, lava formations) he may avoid any definite consideration of plankton, and in a great deal of geologic work plankton may be ignored or else discussed in collective terms having little significance in relation to those organisms as a comprehensive group. But one can not go far in historical geology or structural geology without definite reference to certain types of plankton. Concerning these types he is driven to inquire at once as to the actual or relative extent in space and time of their contributions to geologic structures, the methods of their making these contributions, and the influence of such contributions upon associated features of geologic changes. These inquiries lead naturally to others as to the conditions of existence of the organisms which made the contributions, the conditions which decided the location, extent and texture of the contributions, and the periodicities indicated by their present aspects. Investigations along such lines can not be made fully satisfactory without examination of the pertinent characteristics of typical living representatives of the different groups under scrutiny. (If one should wish to get the best understanding of the behavior and manner of life of a dead dog of unknown history he would study the nearest of kin observable amongst live dogs.) Prominent in this examination must be the question as to why they congregate most in certain areas, why they are absent in certain other areas and why they differ in abundance in a given area at different periods of time, long or short. Presumably, it may appear to some geologists that understanding is not complete unless attention is given to the possibilities of influence of many kinds of plankton (and other organisms) which left no permanent record but which must have played an important part in relation to the activities of those which did leave permanent record, aiding them in obtaining food or competing with them for particular necessities of life. But, however wide his investigations may go, it is not probable that a geologist will demand solutions to these problems in exact details

of small units. He is accustomed to dealing in large units of time and space and his background of millions of years and of geologic horizons inclines him to prefer inclusive statements and general units if they can be made to answer his purpose. Even an "oil geologist," who may be supposed to constitute an exception to this generalization, is primarily interested in exact determination of foraminifera and diatoms because he wants to use them as identification marks for strata which may or may not be promising for oil. He gives little attention to other features or relationships. Briefly, it may be said that a geologist's approach to plankton problems is with the definite intention to study them only to the extent necessary to give him a clue to the solution of his particular set of geologic problems.

There have been, and still are, many group specialists giving attention to marine plankton of one type or another; *e.g.*, copepods, arrow worms, pteropods, tunicates, coelenterates, dinoflagellates, foraminifera, radiolarians, diatoms and bacteria. Many of these specialists have no interest in plankton organisms except that of discovery of new species and varieties, or at least new records of occurrence. For such as these only one plankton problem exists and it is extremely simple, amounting merely to the collection of material which may be expected (or at least hoped) to yield one or more specimens "new to science." But there is a considerable number of specialists whose interests are broader. While they like to find new species and varieties and new records of occurrence, they also wish to know the local conditions which are, or may have been, responsible for these new discoveries and to understand the fundamental conditions responsible for the close similarity of representatives of known species and varieties over wide oceanic areas. Through this broader interest a few may be led to a comprehension of the need for understanding the ocean as a unit of environment rather than as a mixture of environments containing certain features capable of arbitrary separation for examination and for use in explaining phenomena exhibited by the particular plankton group. I regard this difference in comprehension as a matter of importance because it seems to me that observations on any oceanic feature (temperature, for example) are more likely to receive reliable interpretation from a biologist who regards temperature as an attribute of the oceanic whole than it is from one who regards temperature as an abstract phenomenon involved in no essential relationships to the sea. At best, the approach by one who is a specialist from personal preference will be by expansion from the investigation of his particular group of organisms to investigations of the influence of associated organisms and of chemical and physical phenomena upon the characteristics regarded as significant in his specialty. Obviously, the degree of expansion from the basis of his specialty will vary enormously with the inclinations of the investigator and with his control of resources and facilities. Theoretically, expansion might proceed along practical lines to the limits of the plankton or of the whole oceanographic field. Practically, it is generally confined to a few of the more obvious of associated phenomena and to minor excursions in their direction.

It may be surprising to some people to suggest that professional politicians may have any concern in plankton investigations or that they have seriously influenced the direction and progress of such investigations, but it is certainly true that they have taken interest and exerted influence. In practical discussion of plankton problems it is therefore pertinent to inquire as to what views of these problems influence the actions of a politician toward them. With rare exceptions his sole interest is in the

personal advantage which he may derive from attention to such problems. Usually such advantage may be obtained in one of two ways: first, by promoting some investigation favored by his constituents or appearing directly beneficial to them; second, by promoting some highly spectacular investigation which either has practical values or which can be veneered with a show of practicality. A man from an oyster-producing section would take an interest in the extent of use of plankton for food by oysters and in the possibility of cultivating some kinds of plankton to help increase quantity and certainty in oyster production. There his interest would usually end and he might be a detriment rather than an aid to investigations calculated to reveal the character and relationships of plankton as oceanic phenomena. Perhaps it is not too much to say that whatever the desiderata agreed upon by scientific experts proposing a program of investigation of marine plankton it can not be placed in effective operation until it has been more or less revised to conform to the views of one or more individuals primarily interested in its relation to their standing with the public. Evidently this is a good point to introduce an assertion (which is also pertinent to other connections) to the effect that one of the most important features of plankton problems is that including the human influences involved in their solution.

So far I have been discussing the natural avenues of approach of individuals who usually would be content with broad statements and gross terms of solution of plankton problems, or of those who would be satisfied with incomplete statements and limited terms of solution if bearing obvious or superficial relationship to some problem already holding a commanding place in their estimation. Now I wish to speak of two who (theoretically at least) have so much in common that their approaches must be almost identical and their differences must be found mainly in the characteristics of materials handled and in the consequent modes of operation. I refer to the chemical oceanographer and to the biological oceanographer, the latter of whom, with equal propriety, may be called an ecologist.

In what way does a chemical oceanographer differ from a chemist examining sea water? Essentially in the objective toward which he strives. The chemist who examines a sample of sea water may do it as thoroughly and accurately as the chemical oceanographer, but his tendency is to be satisfied with his results and to regard his investigation as completed when he feels sure that he knows fully the chemical characteristics of that sample. Not so the chemical oceanographer. He regards the sample as merely an illustration of what could be found in a sample of water taken from the ocean at a certain time and place and preserved under a certain set of conditions. He knows that there are thousands of cubic miles of sea water which may differ from that sample in a number of interesting and important details, and he knows that a true understanding of the oceanic mass as a chemical mixture can be obtained only by detailed examination of all parts under all of their circumstances of existence. It does not matter that he realizes the impossibility of reaching that objective, because every step that he takes toward it brings vast returns in establishment of probabilities and in practical approach to understanding of fundamental features and of normal trends in changes of relationships. In the plankton he recognizes one of the most prolific sources of localized changes in chemical characteristics of the water as a fluid mass, and in it he also recognizes one of the most disturbing substances suspended in this fluid. He recognizes, or soon learns, that some kinds of chemical change are closely related to particular species of plankton

and that these changes may vary somewhat according to the condition of the organisms. It is evident, therefore, that he is interested in small units; in daily or hourly changes, in species or even varieties, in age, in activity and in other features of plankton existence which demand close scrutiny.

The biological oceanographer reciprocates most of the technical interest of the chemical oceanographer and adds some of his own. In superficial appearance his view of the ocean is somewhat different since he regards it primarily as the residence of groups of living things definitely specialized to meet its conditions. In practice this appearance tends to be lost because he can not account for numerous characteristics of structure and behavior without using the view-point of chemical and physical oceanographers. For some of his solutions of plankton problems he need not use units so small as those generally required by the chemist, but for many f them his limits must be just as rigid and just as restricted. Considering the ocean as a whole, plankton problems, no less than others of great magnitude, present certain broad features for preliminary attention. First, after finding that such things do exist in the ocean, is the problem of finding what they are, of naming them and describing them, and of classifying them so that any questions concerning them may be intelligently discussed. With such things under way or accomplished for the ocean as a whole (or for any designated part) indefinite series of questions and derivative problems crowd for attention. From these some may be selected as basic in much the same way as those just mentioned. For example, there is the question of geographic distribution: is plankton present throughout the ocean, or any designated part thereof? Then there is the question of distribution in time: is plankton always present where found (or absent where not found); is it present at all seasons of the year and for indefinite periods of years? Again there is the question of vertical distribution: is plankton found at all levels or at particular levels at all places and times? Also there is the question as to whether all components of the plankton group are alike in respect to these things and with respect to abundance in all such relations, and if not as to what the peculiarities of unlikeness may be. Having established a knowledge of normal conditions with respect to these points, it is possible to attack such subsidiary problems as those of particular relations to temperature, salinity, oxygen content, alkalinity, competing organisms, beneficial contacts with other organisms, injurious contacts with such organisms, influences affecting life histories, influences affecting abundance at different times and places, and indefinite numbers of other problems.

THE AMERICAN PLANT MIGRATION

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ALPHONSE DE CANDOLLE'S famous book, "Origin of Cultivated Plants," ranks among those monumental productions of science which, although written a generation ago and on numerous points out of date, will always remain young and act as a stimulus to fresh research for generations to come. Botany and agriculture, as well as history and ethnography, have advanced so rapidly since his day that many are now qualified to add new contributions to the problems discussed by him, but no one at the present time would be able to recast his book so as to make it conform to modern progress. An alliance of many scholars—botanists of all shades and grades, agriculturists, horticulturists, archeologists, orientalists, historians, etc.—would be required to cope adequately with a task of such magnitude. Should such a plan ever be considered, it is hoped that a fundamental deficiency in de Candolle's book will be adjusted. One may peruse this great encyclopedic work many times, our memory may retain a number of facts pertaining to this or that plant, as our personal inclinations may lead us; yet no lasting impression will remain on our minds as to the significance of plant cultivations in the development of mankind.

The reason is obvious: the subject is not presented in correlation with human culture. The division of the book is purely mechanical: there are five main sections dealing with plants cultivated for their subterranean parts, for their stems or leaves, for their flowers, for their fruits and for their seeds. Under these botanical categories, the most heterogeneous plants are arranged and succeed one another, regardless of time and space, with no bond linking them together. We are thus confronted with a collection of historical essays or sketches in which subjects historically interrelated are scattered and widely separated, without any attempt at correlation, coordination or pragmatic history-writing. A wild plant is a given fact of nature; the cultivation of a plant presupposes human interference and care, and must therefore be regarded as life and movement in the long career of man. Cultivated plants are an essential element in the history of human economy and civilization, and their study must be grasped in the sense of a cultural movement. In the same manner as many other cultural ideas and inventions, plants have migrated at all periods, and continue to migrate and expand under our own eyes. The great plant-migrations mark the lines in the march of civilization even more clearly than other departments of human endeavor, because agriculture and all concomitant features represent the most stable and unchangeable factor of our economic life. In order to be significant and fruitful, the history of cultivated plants must be conceived of as the history of plant-migrations.

At the present time almost everything is almost everywhere, and we are anxious to learn whether it was there always, or, if not, how and when it has taken its place. Looking at our country, we recognize without difficulty four strata of plant-cultivations: (1) those peculiar to the aborigines of America, like maize, several varieties of bean, pumpkins,

squashes, sunflower, *Nicotiana rustica*, etc., subsequently adopted by the white settlers, who also succeeded in cultivating wild species of North America, as, for instance, the grape; (2) plants introduced from England in colonial times, like wheat, barley, rye, oats, buckwheat, apple, pear, etc.; (3) American plants introduced from the West Indies in the seventeenth and eighteenth centuries; (4) numerous plants brought over from China and Japan from the eighteenth century onward to the present day.

In countries like India and China, conditions naturally are more complex, the stratification is deeper. In China we find from the earliest times a few cultivations typically Chinese, as, *e.g.*, the soy-bean, peach and apricot; others in common with the Sino-Tibetans or Indo-Chinese, the congeners of the great stock to which they belong, like oats, hemp and many species of pulse and Allium (leek and onion); others, like wheat and barley in common with western Asia, and rice in common with southeastern Asia. From the latter part of the second century B.C. the introduction of exotic plants sets in, inaugurated by alfalfa and grape-vine brought back from Fergana by the first Chinese explorer, General Chang K'ien, and followed by a long retinue of other Iranian and west-Asiatic plants, this great Iranian plant-migration, described in detail in my monograph, "Sino-Iranica," continuing for fourteen centuries. Simultaneously the Chinese absorbed what is now southern China and advanced to Tonking and Indo-China, adopting all the useful plants they encountered in that subtropical area and amalgamating the type of southern garden-culture with their old northern plow-ox culture. The last phase of this development is signalized by the introduction in the sixteenth and seventeenth centuries of a large number of species of American origin, which added a considerable plus to the already naturalized quota, with the striking result that almost all useful plants of the universe are now embraced by Chinese husbandry.

In determining the steps in the great American plant-migration, the records of the Chinese are of fundamental importance, as no other nation has preserved fuller and more exact accounts of agricultural events and innovations. It can hardly be fortuitous that all plants without exception, which are justly regarded as American, are placed on record by the Chinese as having been introduced into their country in the latter half of the sixteenth or beginning of the seventeenth century. Korean and Japanese traditions move along the same line; and wherever documents are at our disposal, as in Siam, India, Persia and Europe, the same result is echoed from every quarter. Let us suppose for a moment that there were no botany in America, that we were ignorant of the achievements in agriculture of the American Indian and that we did not even possess the European herbals of the sixteenth century which successively describe the novel plants as introduced from the New World—even this being the case, merely on the basis of our experience with the situation in Asia, we might justly claim that, from a historical view-point, all plants like maize, several species of Phaseolus, potato, batata, manihot, tobacco, pineapple, guava, papaya, Anonas, Capsicum, peanut, agava, sunflower, cashew, arnotto, cacao, tomato, prickly pear and many more, must have originated in and hailed from America. All these cultivations and their products were a revelation to the peoples of the Old World and entirely unknown there prior to 1492.

This conclusion is further linked with my conviction of the independence of aboriginal American agriculture. None of the Old World cultivated plants is found in pre-Columbian America; on the

other hand, none of the American cultivated plants occurs in Europe, Asia or Africa prior to the age of discovery. There never was a direct prehistoric interchange of plants between China and Mexico, or between Oceania and Peru; there is not the slightest foundation in fact for such like speculations. The ingenuity and accomplishments of the American Indian in agricultural products are deserving of our highest admiration. The mere fact that the plants cultivated by the Indians had really been brought into a perfect state of cultivation as early as pre-Columbian times permitted the white man's colonization and made the propagation of these cultivations over the Old World possible; what the white man applied to them were solely improved methods of culture. From numerous biological data, as revealed by the differentiation and variation of corresponding cultivated and wild forms, it may be inferred that Indian agriculture must be not centuries, but thousands of years old.

Of all plant-movements, the American plant-migration, although the most recent, is the most extensive, the most prominent, the most universal and the most momentous in the world's history. It therefore merits profound study in every detail. It has encompassed the globe in its entirety, made its influence felt everywhere, changed the surface of the earth and brought mankind together into closer bonds. For the student of Old World agriculture it is essential to have a clear conception of these intrusions, if he is eager to know what plants originally belonged to a certain culture area.

The history of American plants is also more instructive and fascinating than that of any other plant-movement, for each American plant has its distinct and individual type of history: the migration was not a single event that might be told in a few pages, or a series of operations of a uniform character following a definite scheme, but it was a long, romantic chapter composed of an infinite variety of good plots and stories, set off from a picturesque background in a wide perspective. Nearly all the great nations of Europe assume their rôles—Spaniards, Portuguese, Italians, French, English and Hollanders. The scene is laid over a vast area stretching from the Atlantic coast of Canada, New England, Virginia, down to Florida, the Gulf of Mexico, the West Indies and Brazil, as well as along the Pacific coast from the shores of Mexico and Panama down to Peru and Chile. For the first time in history the oceans developed into a great artery of plant-communication, and plants crossed both the Atlantic and Pacific, directly to Europe and Africa eastward and to Asia and the Oceanic Islands westward. It was a world-wide crusade unparalleled in the microcosm of previous ages. The transatlantic and the transpacific migrations were almost coeval, and we face the curious spectacle that in India, Central Asia and Siberia, several American plants, notably tobacco, suddenly clashed in a sort of head-on-collision, by encircling the globe eastward and westward simultaneously.

The gifts of the New World were all of a democratic character and made a world-wide appeal; tobacco conquered all peoples of the globe without distinction, and I know of only a single tribe that does not practice smoking—the poor islanders of Botel Tobago. Tobacco is more universally consumed than any other narcotic, has profoundly influenced the economy of most nations and signally affected social customs and promoted sociability. In a spirit of gratitude, Chinese and Japanese have bestowed on tobacco the name "herb of amiability" (*ai-king ts'ao*), as they explain, "on account of the affectionate feelings entertained toward one another by all classes of mankind since its use

has become general." Tobacco has proved the greatest peace-maker of mankind and contributed in a higher degree than all pacifist movements to the tranquillity, comfort and happiness of an overwhelming majority.

Maize, peanut, batata and potato have added a considerable share to the means of human sustenance, and consequently to the wealth of nations and the increase of population, notably in those countries where the ordinary cereals are of difficult or costly cultivation. Batata and potato, in particular, are invaluable as famine crops, and in times of drought and scarcity have saved the lives of millions of people. In many parts of western, central and southeastern Asia there are numerous destitute peoples cooped up in barren mountain-fastnesses, much like the tribes in the highlands of Peru, now subsisting exclusively on maize and potatoes; and we wonder how they ever managed to live prior to the discovery of America.

The subject of American cultivated plants is so vast that on this occasion I can merely give a brief abstract of some of my results. An extensive manuscript is almost ready and will be published at some later date. One of my results, I hope, may be of particular interest. It was hitherto unknown, at least to those who have widely written on the subject, when and how the potato reached North America. De Candolle merely dilates on speculations to the effect that some inhabitants of Virginia, perhaps English colonists, received tubers from Spanish or other travelers, traders or adventurers, during the ninety years which had elapsed since the discovery of America. Roze, Wittmack, Brushfield, Safford and others, to whom we owe monographs of the potato, are equally vague. It almost grieved me that we should be ignorant of the facts accompanying the introduction of the potato into our country, while almost all other nations have preserved a record of this event; hence I set out to delve in the early history of Virginia, but with no success. Finally, after several years' quest, I chanced to peruse the old "History of the Bermudas," and was at last rewarded by finding the desired information.

In 1613 the good ship *Elizabeth* brought potatoes from England to the Bermudas. The "Historye of the Bermudaes," ascribed to Captain John Smith (1580–1631), by others to Nathaniel Butler, governor of Bermuda from 1619 to 1622, reports this event as follows (p. 30): "In her wer first brought into thes partes certaine potatoe rootes sent from England, the which being planted and flourishinge very well, wer by negligence almost lost; at last, by a lucky hand, again revived from two cast awaye rootes; they have since encreased into infinite store, and serve at the present for a maine reliefe to the inhabitants." It was from the Bermudas that the potato was further transmitted to Virginia. On December 2, 1621, Captain Nathaniel Butler, governor of the Bermudas, sent from "St. Georges, in the Sommer Ilands," to the governor of Virginia (Francis Wyatt) two large cedar chests, "wherin were fitted all such kindes and sortes of the country plants and fruicts, as Virginia at that time and until then had not, as figgs, pomegranates, oranges, lemons, plantanes, sugar canes, potatoe, and cassada rootes, papes [papaya], red-pepper, the pritle peare [prickly pear], and the like" (*ibid.*, p. 277). In the following year, a Virginian "bareke took from the Bermudas twenty thousand waight of potatoes at the least" (*ibid.*, p. 285). All this is on record in the "History of the Bermudas." The fact that potatoes were actually planted in Virginia at the very moment of the first introduction is confirmed in letters sent from Virginia in

1621 and published by Purchas (vol. 19, p. 151): it is intimated there that "in December last they had planted and cultivated in Virginia potatoes and sundry other Indian fruits and plants not formerly seen in Virginia, which at the time of their said letters began to prosper very well."

The potato, accordingly, entered this country, not as surmised by de Candolle, through an alleged band of Spanish adventurers, but in a perfectly respectable manner—from England by way of Bermuda. It is a prank of fortune, of course, that the potato, originally a denizen of Chile and Peru, appears as a naturalized Englishman in the United States. This result is bound to modify to a large extent the entire early history of the potato as it has hitherto been conceived.

The potato had arrived in England about 1586 or a little later. For a long time the belief was entertained by botanists, even by H. Phillips and de Candolle, that the openauk, described among the wild roots of Virginia by Thomas Hariot in his "Brief and True Report of the New Found Land of Virginia" (London, 1588), was to represent our potato, that Hariot had brought his openauk-potato to England, and that from this source it was received by John Gerard, the first English botanist who raised the potato and described and figured it under the name "potato of Virginia." This speculation is erroneous: openauk is not the potato; Hariot does not claim that he ever took tubers of potatoes to England; indeed, he does not at all speak of potatoes, nor does Gerard mention Hariot's name or the openauk in connection with the newly introduced potato. Hariot described openauk as "a wild root found in moist and marsh grounds growing many together one by another in ropes." The potato certainly does not grow in swampy soil, and never occurred spontaneously in the United States or Mexico. Openauk, in fact, represents an entirely distinct plant, *Apios tuberosa*, popularly styled groundnut or Indian potato, a common article of food among the Indians. I am informed by Dr. Frank G. Speck, of the University of Pennsylvania, that in Penobscot there is a word *ponak* still applied to the groundnut. Be this as it may, from the data of the "History of the Bermudas" it is perfectly clear that "the potato was one of the plants which at that time and until then [that is, 1621] Virginia had not," so that it could not have been known to Hariot; and the fact remains that not a single account, report or letter from Virginia up to that date makes any mention of the potato, while after this date it is most frequently mentioned.

The question as to whom is due the honor of having first brought the potato to England is still deadlocked: the documents fail us. The principal testimony around which the history of the plant in England pivots is Gerard's who merely states, "It groweth naturally in America [this, in the language of the period, means South America], where it was first discovered, as reports Clusius, since which time I have received roots hereof from Virginia, otherwise called Norembega, which grow and prosper in my garden as in their own native country." Gerard's lengthy description and illustration of the potato has been harshly criticized, especially in England, but rather unjustly. In my forthcoming book, where the history of the potato in England is treated at great length, I have committed myself to a complete defense of Gerard's account, which is one of fundamental historical importance. Our imagination, of course, likes to attach the introduction of so useful a plant to the name of an individual, especially to one of historical fame. Sir Francis Drake and Sir Walter Raleigh have been considered in this

connection, and it is possible that one or the other may have had a share in the introduction, though documentary evidence is wanting; Raleigh is credited by popular tradition also with the introduction into Ireland.

The potato had to struggle for over a century in Europe before it met with general recognition; a rapid advance in its propagation was made in England only during the eighteenth century, and in France and Germany still later.

The civilized nations of Asia, while they adopted numerous plants from America, have not yet cast their vote in favor of the potato, but treat it rather indifferently or even disdainfully. This attitude is not the outcome of prejudice or an instance of inherited conservatism, as is often insinuated, but has its cause in the system of nutrition which prevails among those peoples and in which there is no place or vital necessity for potatoes. To be sure, the potato is grown almost everywhere in Asia, and is a favorite dish of all poor mountain-tribes, even in China; but nowhere has it deeply affected agricultural economy, nor does it offer a continuous stream of logical development. Not being national, its history is purely local and split into a series of incoherent efforts of a sporadic and isolated character.

On the other hand, the batata or sweet potato was never duly appreciated in Europe, but proved a prize-winner in the Far East. The admiration and enthusiasm, nay, ecstasy with which the batata was received in China, Luchu and Japan has no parallel in the annals of plant-introductions, and its history in those countries is a little romance hardly excelled by any other useful plant. As it has never been recorded from Chinese sources, a condensed digest of the story is herewith presented. In 1593, the province of Fu-kien in southern China, presumably owing to the ravages of a typhoon, was stricken by a famine. The governor of the province, Kin Hio-tseng, dispatched a commission to Luzon in the Philippines with instructions to search for food-plants which might relieve the pitiable plight of his people. Luzon then was thickly settled with Fukienese, who advised their countrymen to take the sweet potato along. The Chinese chronicle has it that the men beyond the sea, that is, the Spaniards, had strictly prohibited the exportation of the species, so that the Chinese were compelled to have recourse to subterfuge.[1] They wrapped cordage around the tubercular roots of batatas, till they had the appearance of ship-cables, and pretended to load their ships with ropes. Thus they safely reached Fu-kien in 1594 and taught their compatriots the cultivation of the novel plant, which was greeted with unbounded joy and which stemmed the tide of famine. In a short time special agricultural treatises and poetical compositions in honor of the batata were produced, and like a prairie-fire its cultivation spread over all parts of the country. The economic value and the highly nutritive properties of the newcomer were at once recognized. It is unmistakably described and figured and carefully distinguished from the many native species of Dioscorea, with which the batata is so frequently confounded: the Chinese still call it the "foreign Dioscorea" or the "Dioscorea of Governor Kin," at whose initiative it was introduced, and state advisedly that it was previously unknown in their country. In 1786 an im-

[1] I have not been able to trace a confirmation of this charge in contemporaneous Spanish sources; while the regulation somewhat savors of Spanish policy, no other example of such rigid exclusiveness is known to me, and I am rather disposed to suspect some exaggeration on the part of the Chinese, prompted by the desire to aggrandize the perilous nature of their venture.

perial order was issued to encourage the cultivation of the batata as a means of preventing famine.

From Fu-kien it was transplanted on the one hand to Formosa about fifteen years later, and on the other hand to the Luchu Islands as early as 1605. At that time the Luchans still formed a kingdom of their own, though recognizing the sovereignty of the Chinese emperor. Nugun, superintendent of the Chinese settlement in Napa, the chief town of the archipelago, presented a native village chief, Masatsune, with cuttings of the plant; he eagerly studied its mode of cultivation and promoted it in his country. In front of Nugun's tomb a memorial pillar has been erected, and he is canonized under the name Mmuushume, that is, Ancestor of the Tuber. On Luchu, where famines are frequently caused by typhoons, the plant has served as a real life-saving device; and as early as the seventeenth century it became thoroughly nationalized and next to rice the most important article of food; it is still the daily bread of the islanders.

A Japanese farmer, Maeda Riuemon, a native of the province of Satsuma, made the acquaintance of the batata while paying a visit to Luchu in the latter part of the seventeenth century. On his return home he introduced its cultivation into Satsuma, and from there it was disseminated over the northern provinces of Japan. Riuemon's tomb is known as Kara-imo-den ("Temple of the Sweet Potato"), where every spring and autumn the soul of this simple farmer receives offerings from his grateful countrymen. The earliest Japanese treatise on agriculture, the Nogyo-zensho, written by Miyazaki Yasusada in 1696, gives a very full account of the nature and method of cultivation of the batata, and was followed by two substantial monographs in 1716 and 1734. During four years of scarcity, in 1832, 1844, 1872 and 1896, the people of Japan were saved solely by sweet potatoes. The nomenclature follows suit with the historical facts: in Luchu it is known as the Chinese Dioscorea, in Satsuma as the Luchu Dioscorea, and in the rest of Japan as the Satsuma Dioscorea.

De Candolle and all previous investigators, who blindly followed him, were misled by a superficial statement of Bretschneider, who according to de Candolle "has proved that the species is for the first time described in a Chinese book of the second or third century of our era." This, however, is a fallacy and refers to a species of *Dioscorea*, not to *Convolvulus batatas*. This bulwark of an alleged Asiatic origin of the batata, heralded in numerous books, has now fallen. In de Candolle's justice it must be added, however, that he clearly visualized "powerful arguments in favor of an American origin, and that the latter appeared to him much stronger." But there was no prehistoric interchange of the plant between the New and Old Worlds or *vice versa*, as further intimated by him; the plant is decidedly one of American origin and migrated into the Old World only after the discovery. In fact, there is not a single document from which a pre-Columbian existence in Asia or Africa of the batata might be reasonably deduced. In India it makes its appearance toward the end of the sixteenth century as an introduction due to the Portuguese, and is known in all Dravidian languages under the Portuguese-American term *batata*. On the Moluccas it is called *castilian*, on Java and Bali *catela*, based on Castela-Castilian. It is maintained even by serious scholars that the batata has been a native of the South Sea Islands since ancient times. I fail to see any tangible evidence for this opinion. There is usually confusion with other species like *Ipomoea mammosa*, a Convolvulus-like plant with an edible root, but of a distinct botanical character; this is a native

of the Moluccas, where it is also cultivated, and this is probably the batata mentioned by Pigafetta on the Moluccas in 1521. The early Spanish records, *e.g.*, those relating to the discovery of the Solomon Islands, mention taro and two kinds of yam, but not the batata, and the Spaniards coming from South America were surely familiar with this plant. Batatas, together with maize, squashes and *Phaseolus pallar*, were introduced from Peru into Tahiti by a Spanish expedition of 1772 under Don Domingo Boenechea, and a few years later Andia y Varela reports that the Tahitians grow two or three varieties of it. The Maori of New Zealand make a clear distinction between their native species and that subsequently introduced from America.

Finally, there is the testimony of the early discoverers of America and the contemporaneous European botanists, above all that of the great Clusius, who visited Spain in 1566, where he observed and described three varieties of batata. He states that it grows spontaneously in the New World, whence it was first brought over to Spain. "We sometimes have them fresh in Belgium," he adds, "but they will not germinate here, the country being too cold." Nicoloso Monardes, physician of Seville in 1572, likewise discusses the batata as a native of America and as widely cultivated and consumed in Spain in his time.

The history of the pineapple is of particular interest because it is so strikingly individualistic, quite in distinction from that of maize, which is so impersonal. A plant of such remarkable characteristics challenged the attention of all observant travelers. There is hardly any other plant the history of which is illuminated by such a flood of interesting documents. More than two hundred documents bearing on the pineapple have been brought together by me, and these have enabled me to trace the steps in its migration with a fair degree of accuracy.

The pineapple, the king of all fruits, as it has frequently been styled, belongs to the order Bromeliae, which consists of twenty-eight genera and 176 species—all natives of the American continent and insular groups, whence their distribution to many parts of the Old World has taken place. It is a particularly interesting point that in consequence of long-continued cultivation the highly cultivated varieties of *Ananassa sativa* have become seedless. This characteristic feature was emphasized as early as 1557 by André Thevet—a sure manifestation of the great antiquity of the cultivation in pre-Columbian America. Seeds are so scarce in the West Indies that there is seldom more than a single one found even in thirty or forty fruits. The plant is therefore usually propagated by means of crowns, slips, suckers and rattoons. The crown furnishes the most vigorous plants and yields the finest products. Plants are raised from seed only for breeding purposes, with a view to obtain novel varieties, but it requires from ten to twelve years to mature a plant from seed. The wild pineapple, on the contrary, is full of seeds, but small, seldom larger than an apple, stringy and rather acidulous in taste. It is only due to the process of cultivation that the fruit has acquired its large size and superior flavor. This was an accomplished fact when the first explorers of the Antilles and South America made its acquaintance.

The documents at our disposal warrant the conclusion that at the time of the conquest the pineapple as a thoroughly cultivated plant occupied the area of Brazil, Guiana, Colombia, parts of Central America and the West Indies. As early as 1519 it is mentioned in Brazil by Pigafetta as "a fruit resembling a pine-cone, extremely sweet and savory, in fact the finest fruit in existence."

André Thevet visited Brazil in 1555–56 and correctly figures and describes the fruit under the Tupi name *nana*. It was then medicinally employed by the natives, who also made a strong wine from it. Thevet's statement, that "the fruit bears no seed whatever and is hence planted by means of small slips, as fruits are grafted in our country," bears out the fact that the cultivation in Brazil must have been many, many centuries old. Jean de Lery, the Huguenot clergyman, who came to Brazil in 1557, is the first to employ the word *ananas* as being derived from the language of "the Savages." Christoval de Acuña, in 1639, found the Indians of the Amazon Valley using pineapples as food. In his "Discoverie of Guiana" (London, 1596), Sir Walter Raleigh speaks of "great abundance of pinas, the princesse of fruits, that grow under the sun, especially those of Guiana."

Although not mentioned by Columbus himself, the pineapple is placed on record by his contemporaries and epigones, who made use of his and his companions' diaries, letters and reports; first of all, by Peter Martyr d'Anghera, who offers three notices of the curious plant in the second and third decades of his *De Orbe Novo*, first published in 1516; this is the earliest record of the pineapple in existence. Martyr describes it as an herb resembling a pine-nut, artichoke or acanthus, raised in the gardens of the West-Indian islanders, worthy of a king's table; King Ferdinand of Spain had eaten a fruit shipped from Darien and awarded to it the highest praise. A lengthy, though somewhat verbose and cumbersome description, is inserted in Oviedo's "Historia general y natural de las Indias" (1535). There are numerous old accounts for Cuba, Porto Rico, and other islands, where many varieties were raised at an early date.

In ancient Peru, the pineapple was unknown: it is conspicuously absent in Peruvian archeology, not being found in any graves, nor is it represented on pottery vessels. Joseph Acosta, in his "Historia natural y moral de las Indias," states expressly, "It does not grow in Peru, but is carried there from the Andes, and this fruit is neither good nor ripe." Cieza de Leon mentions it only as growing in Cali, a Spanish settlement of Peru, together with a series of plants introduced from Spain and the West Indies. Finally, there is a formal, though somewhat belated, testimony to the effect that the plant was introduced into Peru from Brazil. G. Piso, in 1658, asserts that, according to a statement of trustworthy old natives of Brazil, the fruit was transmitted from Brazil to Peru. The oral testimony of old men, especially with reference to an event that dates back at least a century, is somewhat subject to suspicion, but there is no doubt of the fact that the pineapple was not imported into Peru until after the conquest. It is not amiss to emphasize this point, in view of the information given in the "Treasury of Botany" that the pineapple first became known to Europeans in Peru, where it is called *nanas;* and most of our dictionaries, even the Oxford New English Dictionary, wrongly define *ananas* as a Peruvian word. In fact, this word does not exist in any Peruvian language, or in Spanish. From the reports of Thevet and de Lery it is perfectly obvious that the word originated in Brazil, where it still occurs in Tupi. The Brazil Portuguese term has conquered all vernaculars of Africa, India, Malaysia, and all European languages, with the exception of modern English, pineapple being modeled after Spanish *piña*, while in seventeenth and eighteenth century English *ananas* was still frequent.

The antiquity of the fruit in Mexico and among the Maya does not seem to be well authenticated: Sahagun apparently does not mention it. Geronimo Benzoni, from Milan, who sojourned in Mexico

from 1541 to 1555, gives a brief, though colorless, description of the plant in his "History of the New World" of 1578, without special reference to Mexico. Francisco Hernandez, in his "Rerum Medicarum Hispaniae Thesaurus" (Rome, 1651), writes that he found the pineapple (termed by him *Pinea indica*) in the warm regions of Mexico and Haiti, and furnishes a drawing of it under the Aztec name *matzatli*. This comparatively late evidence, however, does not suffice to regard the pineapple of Mexico as pre-Columbian.

According to W. Popenoe, the pineapple was doubtless cultivated by the ancient Maya, and is still grown in several gardens near Copan. This conclusion, however, is inferred from present-day conditions; it is retrospective and remains to be substantiated by more solid data.

In the West Indies the pineapple occurs solely in the state of cultivation or occasionally as a fugitive, while without any doubt this cultivation is of ancient date and was an accomplished fact at the time of the Spanish conquest. The wild congeners of the plant and many other representatives of the genus, however, are to be found in Brazil and Guiana. It is therefore reasonable to regard Brazil as the mother-country of pineapple cultivation: Brazil was one of the great centers of aboriginal agriculture, from which also emanated the sweet potato, the cassava, the peanut, Capsicum, several species of beans, and others.

The pineapple was introduced to Bermuda from the West Indies under Captain Tucker (1616–19), third governor of the islands.

An early attempt to acclimatize the fruit in Virginia proved a failure. W. Strachey[2] reports in 1614, "The rootes of the delicious Indian pina, sett in a sandy place, thrived, and contynued life, without respect had of yt, untill the cold wynter and the weedes choaked yt; yet is this fruict said to be daintye, nice, and of that nature, that noe art or industry hath be found out hitherto that could preserve yt in any clymate but in the West Indie Islands only." In December, 1621, pines were shipped to Virginia from Bermuda, together with potatoes, sugar-canes and plantains, and began to prosper well, as we learn from a contemporaneous document published by Purchas. I have not yet been able to trace any subsequent documents, and do not know what the outcome of these initial experiments was. Pineapple cultivation in the south of Florida is a recent event, not earlier than 1886.

In English literature the pineapple is first mentioned in 1568 in the "New Found Worlde or Antarctike," which is a translation of André Thevet's "Singularitez de la France antarctique autrement nommee Amerique"; for the second time in 1580 in John Frampton's "Joyfull Newes out of the New Found World," which is based on the Spanish work of Nicoloso Monardes. John Gerard, in his famous "Herball" of 1597, is not yet familiar with the plant; but in the second edition of 1633, prepared by Thomas Johnson, it is described and accompanied by a woodcut of the fruit. John Parkinson, in his "Theatrum Botanicum," published in 1640, is more copious in his description, more accurate in his illustration and gives more information concerning its history. He states that the Anana or West-Indian delicious pine was first brought from Santa Cruz in Brazil, where it grows wild, and was thence introduced to the East and West Indies, being not a native of either; in Brazil, it is called by the natives *nana* and *anana*, but by the Spaniards and Portuguese *piñas*.

In 1657 Oliver Cromwell received four pineapples brought back by an embassy

[2] "Historie of Travaile into Virginia," p. 31. Hakluyt Society.

returning from China. This event is alluded to by John Evelyn in his "Diary," where under date of August 9, 1661, he writes, "I first saw the famous Queen pine brought from Barbadoes and presented to his Majesty Charles II; but the first that were ever seen in England were those sent to Cromwell four years since."

Under date of August 19, 1668, we read the following in Evelyn's "Diary":

I saw the magnificent entry of the French Ambassador Colbert, received in the Banqueting-house. . . . . Standing by his Majesty at dinner in the presence, there was of that rare fruit called the King-pine, growing in Barbadoes and the West Indies; the first of them I had ever seen. His Majesty, having cut it up, was pleased to give me a piece off his own plate to taste of; but, in my opinion, it falls short of those ravishing varieties of deliciousness described in Captain Ligon's History, and others; but possibly it might, or certainly was, much impaired in coming so far; it has yet a grateful acidity, but tastes more like the quince and melon than of any other fruit he mentions.

It would follow from this notice that the pineapples of King Charles were imported from America.

Lady Mary Wortley Montagu (1689–1762) writes in one of her letters, dated Blankenburg, December 17, 1716:

I was particularly surprised at the vast number of orange-trees, much larger than any I have ever seen in England, though this climate is certainly colder. But I had more reason to wonder that night at the king's table (in Hanover). There was brought to him from a gentleman of this country, two large baskets full of ripe oranges and lemons of different sorts, many of which were quite new to me; and, what I thought worth all the rest, two ripe ananas, which, to my taste, are a fruit perfectly delicious. You know they are naturally the growth of Brazil, and I could not imagine how they could come there but by enchantment. Upon enquiry, I learnt that they have brought their stoves to such perfection, they lengthen the summer as long as they please, giving to every plant the degree of heat it would receive from the sun in its native soil. The effect is very near the same; I am surprised we do not practise in England so useful an invention.

As to the source from which the two pineapples served at the electoral table of Hanover had come, we receive a bit of information from the philosopher Leibnitz, who wrote about 1714 as follows:

All the travelers in the world would not have given us by their relations what we are indebted for to a gentleman of this country who cultivates with success the ananas, three leagues from Hanover, almost on the banks of the Weser, and who has found out the method of multiplying them, so that we may perhaps have them one day as plentiful, of our own growth, as the oranges of Portugal, though there will, in all appearance, be some deficiency in the taste.

This remark refers to Otto von Münchhausen, who in his gardens not far from Hameln erected large buildings for the express purpose of raising pineapples, in the beginning of the eighteenth century.

Lady Montagu, however, was not quite correct in her surmise that so useful an invention was not practiced in England. In fact, pineapples were produced in English hothouses several years before they were established in Germany. This was first accomplished in the gardens of Amsterdam by means of plants introduced from Java, Surinam and Curaçao; and from Holland the art spread to England, France and Germany. During the eighteenth century, the culture of pineapples in hothouses was understood by almost every gardener in England. There are a number of very interesting treatises on the subject written by practical English gardeners, such as Speechly, Abercrombie and Baldwin, with full details bearing on the numerous varieties then produced. The Fitzwilliam Museum at Cambridge preserves a landscape by Netcher in which a pineapple is introduced. It is there stated to have been the first that ever fruited in England, and that it was produced in the gardens of Sir Matthews Decker, at Richmond in Surrey (in 1712).

Soon after the discovery of St. Helena in 1502 the Portuguese transplanted there the pineapple, together with many other fruits, vegetables, cereals and cattle, all of which flourished abundantly on the island after a short period. There is no doubt that the Portuguese were active in diffusing the plant along the west and east coasts of Africa and on Madagascar at an early date; through their agency the term *ananaz, nanasi* or *manasi* penetrated into the native languages of Africa. In the account of the Dutch expedition to Guinea in 1602, a lengthy description of the fruit and its usefulness is given; its cultivation on the part of the inhabitants of Guinea then was an accomplished fact. M. Hemmersam, in the account of his voyage to the coast of Guinea (1639–45), writes that "the Moors consume quantities of ananas, as they call this fruit, which is like an artichoke; they also cook it, mixing it with palm-oil which they use for all their food in the place of fat; it belongs to the best fruit of this country and makes an excellent dish when sliced and soaked in Spanish wine, but too much of it entails malady." Etienne de Flacourt, who was governor of Fort-Dauphin on Madagascar from 1648 to 1655, has left interesting observations on pineapple culture in the island, which are inserted in his "Histoire de la grande isle Madagascar" (1661). At the same time, the plant was cultivated on Réunion (Bourbon) and Mauritius, as we learn from Du Quesne and François Leguat. The Mauritius variety is of superior quality, and was also introduced into India. About 1660 the Dutch planted pineapples at the Cape of Good Hope. These had been brought over from Java by Georg Meister, a professional gardener, who himself tells this story in his very interesting diary.

About 1550 or shortly afterwards, the pineapple was introduced into southern India by Garcia da Orta, a Portuguese physician, author of the famous "Coloquios dos simples e drogas da India" (Goa, 1563), who mentions it as an introduction from Brazil; but more than that —it is unmistakably described in the Ain-i Akbari ("History of the Emperor Akbar"), written in 1597 by Abul Fazl Allami. The Emperor Jahangir tells in his "Memoirs," under the year 1616, how a large tray of fruit was brought before him, among these pineapples from the seaports of the Frangi; that is, Franks, Portuguese. "Some plants of this fruit," the emperor goes on to say, "were placed in my private gardens at Agra, and after some time they produced several thousands of that fruit."

Huygen van Linschoten, in 1596, describes ananas as one of the best fruits and of best taste in all India, and adds, "But it is not a proper fruit of India itself, but a strange fruit, for it was first brought by the Portingalles out of Brasille, so that at the first it was sold for a noveltie, at a pardão apiece, and sometimes more, but now there are so many grown in the country that they are very good cheap." Nearly all travelers to India in the seventeenth century describe the fruit and eulogize it. François Pyrard, whose peregrinations in the East extended from 1601 to 1611, even enumerates it among the productions of Nepal. It likewise spread at the same time to Bengal, where Nicolao Manucci reported a more extensive cultivation than anywhere else in India, and where the fruit was also preserved; in the latter part of the seventeenth century it advanced to Assam, Burma and Siam. In Assam, more particularly the Khasis hills, as well as in the forests of Ceylon, it has escaped from cultivation, and has thus become seemingly spontaneous, but even these semi-wild plants are still designated by the natives with the Brazil-Portuguese terms *ananas, annasi,*

etc., which, with slight modifications, are echoed in all languages of India and Malaysia, with the sole exception of Tagalog, which has adopted Spanish *piña*.

Before the close of the sixteenth century, the pineapple had reached Malaka and Java. The Malaka product soon achieved a reputation all over the East. In 1637 Peter Mundy, a prominent English traveler, found pineapples planted, while passing through the strait of Singapore, and even on outlying islands as Pulo Tinggi off the east coast of Johor. Engelbert Kaempfer encountered them in 1690 on his voyage from Batavia to Siam on the island Puli Tumon near the east coast of Malaka.

In China we meet the fruit from the beginning of the seventeenth century. It is not mentioned in Chinese records at an earlier date. It is not correct, however, as has been asserted, that the plant reached China through the Philippines. Chinese authors are reticent as to this point, and it is more probable that the Portuguese brought it from Malaka to Macao, where it is still cultivated and whence it was disseminated into the province of Kwang-tung and the island of Hai-nan. From Hai-nan it was transmitted to Fu-kien and Formosa, where it was noticed as early as 1650 by John Struys. On the other hand, it also appears to have entered Yün-nan Province from Burma. Chinese names for it like "foreign jackfruit," "royal pear" or "phoenix pear" are likewise an index of a recent introduction. Pineapple cultivation and cannery have reached a great economic importance in China and Indo-China, the fruit being consumed by all classes of people in enormous quantity, and the fibers of the leaf being utilized for textiles. As to Japan, the fruit was first introduced into Nagasaki by the Hollanders as late as 1845.

WHY WE HAVE EMOTIONS

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THE explanation of the emotional life of man broadly implied in the title may appear to be somewhat ambitious. Like many other explanations all that we can hope to do is to scratch the surface or at best perhaps to dig a short distance down. If in this attempt we strike basic rock we are fortunate, but even then the process of sinking shafts through the rock is only begun. In answer to the general question, therefore, all that we can do is to trace human emotions to more fundamental principles. Having worked for many years in this field, the writer has given some serious thought to the matter of explanation and believes that he has at least a tentative answer to the question raised in the title.

The problem of emotion was one of the earliest to arise in the inquiring mind of man. It was not as insistent in its demands as was the question of reason and intellect, nor did it for so long a time occupy the high seat of honor. In almost every cosmology, however, it finds a place, and nearly every religion deals with it in one form or another. Confucianism centers its influence around *shu*, the sign of the heart, which is expressed in the Golden Rule; Brahmanism makes blissfulness (*ananda*), together with reflection and being, one of the three aspects in the general formula for the godhead; the idea of God the Compassioner, or Rahmān, is deeply imbedded in the Koran, side by side with the fearful torments of a wrathful deity; reverence for ancestors forms one of the cornerstones in the doctrines of Shintoism; and in our New Testament the message that God is love replaces the more austere dogma that Jehovah is exacting and revengeful, as he is described in many places in the Old Testament.

When we scan the horizon at the dawn of occidental science, again we find emotion given a place at least in the twilight. The Greeks hardly ever failed to emphasize the importance of this aspect of our lives, and the great Homeric epics are full of emotions of the gods and the heroes. The "Iliad" begins with the dramatic sentence, "Sing, O Goddess, of the consuming wrath of Achilles, son of Peleus, that has thrust countless woes upon the Greeks." Soon we find the magnificent war-lord Agamemnon so perturbed that "his mighty midriff, black on both sides, heaved with anger, and his two eyes seemed to shine forth like fire." In another connection Apollo's "heart burst with anger." The early philosophers, too, gave the emotions a significant position in their systems of first causes, and Anaximander, six centuries before Christ, makes love one of the indestructible principles of the cosmos, while later Empedocles reduces the universe to earth, air, fire and water, which are attracted to each other by love and repelled by strife.[1]

After this early Greek period emotion no longer attracted the attention of thoughtful writers, who were mainly concerned with questions related to in-

[1] From this it is a far cry to the analysis recently made by Millikan, in an address before the Society of Chemical Industry, when he stated that in addition to the positive and negative electrons, the fundamental elements in the world are helium, oxygen, silicon and iron. But it is significant to note that in this partnership of universal causes iron is the only stranger, while love and strife have turned into positively and negatively charged electrons!

telligence, reason and the will. For Plato, love comprised both the sensuous impulses on the one hand and the soul's highest yearning for eternal beauty, goodness, truth and immortality, on the other. Aristotle in his psychology delicately poised the emotional life of man between reason and desire. A little later Epicureanism built up a philosophy of pleasure, but noted nevertheless that the pleasures of the mind were more desirable than mere bodily pleasure and warned its followers that many pleasures were followed by pain. By this time, however, the question took on moral aspects, and cosmological analysis gave way to ethical culture. When Neo-Platonism and Christianity began to show their influences the emotional life of man was for the most part either discarded as unworthy of discussion or disregarded altogether.

Some philosophers considered this aspect of the human mind only to dismiss it with scant treatment. Descartes remarked that it represented merely the agitation of the animal spirits in the pineal gland; Spinoza called it a confused idea due to fluctuations in the vital stream; and Herbart regarded it for a moment as the discarded waste in the up-building of the mind.

The very fact that these seekers after truth concentrated their attention on that aspect of the mental life which is embodied in the concept of intellect, led them to overlook certain rather startling events which became more and more impressive in connection with the emotional experiences of man. From the philosophical point of view, of course, it was necessary to discover what were the channels through which knowledge came and what were the usual errors in the reasoning process. But insistent problems dealing with other aspects of the mental life clamored for solution from the minds of thinking men. It was soon discovered that human beings did not live by intellect alone. Bitter wars were fought because men were stirred up and fervently aroused. Great issues were often not solved by pure reason or near-reason, but by emotion and sentiment. Then there were human derelicts around: men and women of well-developed wits and mature intellect, but with malformed emotions. They were like high-powered explosive mines swept from their moorings and adrift in the lanes of human navigation. There seemed, moreover, to be massive human icebergs afloat, huge fragments of congealed mind without a spark of emotion left in their lives. Dealing their massive blows with six sevenths of their bulk below the water line, in darkness and in fog, they menaced the morals of mankind. The life stream that was once a limpid and refreshing mountain brook became now the frigid fist of death. So in all time, not only in our time, emotionless fiends as well as frenzied fiends have claimed their victims. This human flotsam and jetsam soon came into the focus of scientific scrutiny and new questions were raised in the thinking world.

The task became complicated. From many new angles the questions concerning the emotions pressed for answer. Patients under care and treatment had developed curious emotional disorders. Manic-depressive psychoses, hysteria and schizophrenia were being noted and described. The testing of intelligence also raised new issues with respect to persistence of effort, interest and honesty. Every one wished for facts that were not yet at hand and are indeed still wanting. Partly because of this prolonged neglect of an integral portion of our mental lives we are now in dire need of reliable information in regard to the emotions of man. But the quest is on.

The direct drive in this direction can be dated from the middle of the last century. Darwin had brought forth his

"Origin of Species" in 1859. In 1873 he had already applied his three great principles of emotional interpretation to human as well as to animal expression of emotion in his monumental work, "The Expression of the Emotions in Man and Animals." These three principles were: (1) serviceable associated habits; (2) antithetic attitudes, and (3) neuro-muscular response. The first principle stated that voluntary movements made through many generations and expressing a useful biological purpose tend to survive under similar conditions, sometimes in a weakened form, even when no longer useful. For example, in the disdainful grin of superiority, the canine teeth are bared even though we no longer put them to use to prove that superiority. The second principle states that when an organism has made movements that suit a certain situation, these movements are frequently followed by expressions which are exactly opposite to the first group. For example, when an organism sets itself for an attack and finds that the object of attack is really a friendly being, just the opposite movements will result, *i.e.*, those of almost excessive crouching in the attitude of servility. The third principle refers to the apparently useless movements which are due to direct nervous excitation, like the trembling which accompanies fear and the condition of cataplexy which results in certain situations of fright and awe. Several outstanding contributions to the subject of emotional expression had already been made and are noted by Darwin in his introduction.[2]

But from the psychological point of view the reduction of the emotional life simply to movements and changes of or within the body affords an insufficient explanation. The study of the bodily accompaniments of emotion is an exceedingly fruitful one—one that has developed indeed an entirely new series of techniques and one that has far extended our physiological and biological knowledge. Behind it, however, lies the more intricate problem of the relation between mind and body, than which there is probably no more perplexing question, unless it be the more fundamental metaphysical issue of the ultimate reality of the universe itself. Since the relation between mind and body has already received thorough-going consideration in scores of articles and dozens of volumes, a paper of this length can give it only relatively scant notice.

In order to deal with the question satisfactorily we shall have to raise and answer the logically prior query, what is the nature of emotion? Experimentally, of course, the problems of description and explanation may proceed side by side and thus become mutually helpful. Similar situations have arisen in sciences other than psychology. For example, why we have an electrical flow of energy, may be answered after a fashion before we have anything like a final reply to the question, what is electricity? We can discuss the question, why we have brains, without having settled the more fundamental question, what really is the brain? For a moment let us digress therefore to face the issue of the nature of emotion.

The conception as well as the terminology is becoming more stabilized. It is clear that originally the term and its corresponding conception had a strong physical, sometimes even a geographical and meteorological implication. Indeed, the first appearance of the term indicated a migration of peoples. In 1579 Fenton so used the term: "There were

[2] Among them are Sir Charles Bell's "Anatomy and Philosophy of Expression" in 1806; Moreau's edition of Lavater, "L'Art de Connaître des Hommes" in 1807; "The Physiology of Mechanism of Blushing" in 1839 by Dr. Burgess; Dr. Piderit's "Grundzüge der Mimik und Physiognomie," 1858, in which appears his "Geometry of Expression"; and Gratiolet's "Concerning the Physiognomy and Movements of Expression," 1865.

. . . great stirres and emocions in Lombardye." In 1773 we read of an "emotion of the center of gravity," and in 1755 of an "emotion of thunder in the air." Addison in his *Tatler* (1709), described a political agitation under the title, "Accounts of Publick Emotions, Occasion'd by the Want of Corn." Gradually this notion of agitation and commotion is transferred to the human and animal body, and we are not sure whether the experience of emotion or the bodily movements or both are referred to. For instance, in John Locke (1693) we read:

> I think nothing need to be said to encourage it [bathing in cold water] provided that this one caution be used, that he never go into the water when exercise has at all warm'd him or left any emotion in his blood or pulse.

Many of us recall a similar situation in Hawthorne's "House of Seven Gables" (1851), where he writes, "Mellow melancholy, yet not mournful, the tones seem to gush up out of the deep well of Hepzibah's heart, all steeped in its profoundest emotion." In French the term is the equivalent of the English, while in German the more technical term is *Affekt*, but one of the more general terms is *Gemütsbewegung*, which means a movement referred to the life of feeling and will.

In fine, it becomes clear that the background of emotion is distinctly one of movement or commotion and that there has always been a strong bodily implication. Even the Greeks, as we noted above, were prone to locate the emotional life, if not indeed the whole mental life, in some physiological organ of the body.[3]

[3] Dr. A. Sophie Rogers in an unpublished manuscript made a complete study of the places where the mind was located in many writers among the earlier Greeks and Romans. The organs affected by emotions in one form or another included: body in general, brain, breast, diaphragm, gall bladder, heart, intestines, jaws, kidneys, liver, lungs, limbs, medulla, spleen, stomach, throat, viscera.

Aside from the gross psychophysical error which still persists when uninformed individuals place the non-physical mind into a physical brain, it is to our point here to notice that a reference to the body existed among the early thinkers.

Before we go further, however, into this matter of the interrelation of mind and body, we shall have to face for a moment and in a preliminary fashion the question of the nature of emotion itself. From the large number of descriptions of emotions found in the literature we can gather together at least five specific factors which are usually definitely stressed.

First, with few exceptions, an emotion is recognized as a complex and not a simple experience—one, therefore, which could not be found in comparatively simple organisms. Our comparative psychology teaches us that not only the biological life but also the mental life of these organisms is devoid of the more complex processes. But emotions as commonly described are extremely intricate and all-absorbing in the sense that all mental processes are intimately and most completely dissolved in the entire mass or pattern which we call emotion. At the moment of seizure there is nothing left in the total experience of the individual that is left out of emotion. This is one reason why it has been difficult to analyze it by direct observation or without the expertness that comes from practice.

Secondly, the emotional experience as we define it passes with a high degree of vividness and clearness. It is a very lively affair and does not go off in a half-cocked condition. Mind is all there—no one ever has had an emotion while he was half asleep or half awake. Even in sleeping the limited number of emotions that occur are very vivid experiences and often result in awakening the individual.

Thirdly, the entire process or experience follows a temporal pattern and an order of bodily responses which are largely inherited and which can incidentally be traced on that account to organisms biologically related to mankind. The march of mental events, in fact, the entire mental picture of emotion in general and of every kind of emotion in particular is so much a matter of our common inheritance that we can find more resemblances than differences from individual to individual. The same can be said about bodily responses. Here, too, there are individual idiosyncrasies. In anger, for instance, one person may flush in the face, another behind the ears, a third in the back of the neck, while a fourth may grow pale in one or more of these regions. There are similar differences in the type and degree of other bodily responses, including, as we have discovered, the character and amount of electrical resistance of the body. One must not omit, of course, the changes due to acquired control and inhibition of voluntary muscle systems, including some so-called involuntary ones. The writer has found, for example, two students of his, both girls, who could voluntarily open and close the pupils of the eyes. And the medical journals have reported at least fifteen instances of the voluntary control of the heart beat. All these bodily responses have been most extensively studied in the literature.[4]

Fourthly, emotion is unique in that it is founded upon a distinctive attribute of the mental life known as feeling or affection. Some attempts have been made to reduce these affective qualities, now predominantly known as pleasantness or unpleasantness, to some such sensory level as pain and tickle, or as dull and bright pressure.[5] But on the whole these positions have not been widely accepted. Several discussions, like those of Dunlap, Royce and Wundt, have aimed at a multiplication of these qualities. But their findings have not been corroborated by further experimental work.[6] This unique aspect presents its own problems and difficulties. Bentley believes feelings to be like a haze or mist and refers to them as affective tone; Calkins calls them "attributive elements of consciousness"; Pillsbury calls them subjective in reference; Seashore works feeling into a tridimensional diagram as relief or depth, and Titchener remarks the absence of the attribute of clearness or vividness.[7]

Fifthly and finally, emotion is described as referring to or involving the cognitive function of perception or idea, presentation or representation. Most

[4] H. F. West and W. E. Savage, "Voluntary Acceleration of Heart Beat," *Arch. of Intern. Med.*, 22: 290–5, 1918.

[5] The outstanding instances in the literature are principally found in the following writings: Carl Stumpf, "Ueber den Begriff der Gemüthsbewegung," *Zeits. f. Psychol.*, 21: 47 ff., 1899, who in the main reduces the feelings to such cutaneous patterns as tickle and itch; W. James, "Principles of Psychology," 1890, Vol. II, Chap. 25, where, in his famous theory of emotions, he reduced the total affective pattern to visceral sensations; see also his article, "What is Emotion?" *Mind*," *O. S.*, 9, 189, 1884; this extreme position was somewhat modified in his later discussion, "The Physical Basis of Emotion," *Psychol. Rev.* 1: 516–29, 1894; J. P. Nafe, "An Experimental Study of the Affective Qualities," *Amer. J. of Psychol.*, 35: 507–44, 1924. Another possibility is contained in the statement of K. Dunlap, "Elements of Scientific Psychology," p. 317, 1922, "The most plausible processes as a basis for these feelings have been claimed to be the tumescence and detumescence of the erectile parts of the generative organs, but this assumption is merely tentative, and hardly yet sufficiently indicated as a working hypothesis."

[6] K. Dunlap, *op. cit.*, p. 315 ff.; J. Royce, "Outlines of Psychology," 1903, p. 176 ff.; W. Wundt, "Grundzüge der physiologischen Psychologie," 6th edition, 1911, Vol. 3, p. 199 ff.

[7] M. Bentley, "Field of Psychology," 1924, 84. M. W. Calkins, "First Book in Psychology," 4th Rev. Ed., 184. W. B. Pillsbury, "The Fundamentals of Psychology," 1916, 448 ff. C. E. Seashore, "Introduction to Psychology," 1924, 304 ff. E. B. Titchener, "A Beginner's Psychology," 1915, 79 f.

writers point out that when we experience an emotion, we become aware at the same time of a specific object, event or situation in the environment which may be or may not be physically present but which elicits the emotion and toward which the specific emotion is directed. In other words, objectless emotions have been found with only extreme rarity. Some that have seemed to be objectless of course contain ideated objects not physically present. As James further points out, if no external causes are present, the causes, especially in pathological persons, are bodily causes that thus become objectified. Anger, fear, love, and all the rest, are directed toward objects of which the experiencing person is aware but which may or may not be physically present. Sometimes if no object readily presents itself for such emotional outlet, it is mentally created. A writer on adolescence remarks that many young people who write diaries personify the diary because no one else is considered worthy of these confidential statements and the attendant emotions. Children sometimes create fictitious companions. Some one told the writer the other day of an interesting example in which a boy developed a series of adventures and a life history for an imaginary hero whom he called "Grease-Fight," concerning whom a large number of emotional situations were evolved.

Now that we have the picture of emotion sketched in sufficiently for the purpose of this discussion, we may answer serially the question raised in the title by referring to each one of the several features outlined. Some of these items have mutual interrelations and can therefore be gathered in groups.

The problem of the complexity of the emotion is one which has not been fairly faced by way of explanation. Krueger[8] has just recently suggested one explanation for it, and others have barely touched upon it. Basically, it is a genetic question, and the answer to it forms the main contention of the paper. Much has been written about the theory of emergent evolution for mind in general. Notably Lloyd Morgan and Patrick have shown how mind may be considered as one of the latest appearances in the upward urge of evolution. In the same way each particular phase of mind can be said to emerge as a form or pattern when mind itself has arisen as one of the emergent aspects of natural life. Emotion, then, may well be one of these patterns or configurations that have appeared from time to time as mind became more and more complexly developed. It must not be surmised at this point that emotion emerged full-fledged out of the mental life as Athena was said to have been born in complete armor out of the head of Zeus. It is an average concept with many gradations and several approximations. Any gradual development offers the same difficulty. One might well compare the homely illustration of a rose passing from bud to flower. Emotion, moreover, as far as man is concerned, is itself only an intermediate step in the development of the mental life from its feeling aspect. We have in man what appear to be still more highly developed feelings in the so-called tender emotions or sentiments.

It matters little what was the original process out of which emotion has developed or what was the precise order in the genetic procession. Titchener claims that sensation and affection are both derived "from a common mental ancestor."[9] In his view, sensations were gradually more highly developed while the growth of the affective process was arrested. Hence its scarcity of qualitative and quantitative attributes and its lack of end-organs. He hazards a guess that the free afferent nerve-endings serve as its peripheral organs. Ribot, on the

[8] F. Krueger, "Komplexqualitäten, Gestalten und Gefühle," 1926.

[9] E. B. Titchener, "Textbook of Psychology," 1919, p. 260.

other hand, points to the purely affective life of the very young child, but he does not deny that even in the intrauterine period there may be "internal sensations" or cœnaesthesia,[10] the technical name for sensations from within the body, or what Warren calls "systemic sensations." In other words, Ribot believes that we can have a mind that is made up entirely out of simple feelings.

Be that as it may, in children and probably in the race, emotions are later developments. Preyer found fear, which was the first emotion to appear, present from the second day on; Perez from two months on, and Darwin at four months and after. Watson finds the fear reaction present at birth, even in decerebrate infants. But since all these studies describe only the responses and can not describe the accompanying experiences, not much can be gained for our present purpose from such accounts. Almost all writers agree, however, that emotions are not experienced in comparatively simple organisms, although in these there may be present some form of sensory experience with or without some phase of feeling. Only when the perception or ideation of a total situation has been developed and not merely the bare sensible quality that follows upon a stimulus can anything like an emotion arise. And just as the instinct is more than a congeries of reflex reactions, each one responsive to its peculiar stimulus, so the emotion is more than a summation of feelings. This total perception is apparently present in forms as low in the scale of evolution as wasps and spiders, but is not present in protozoa and many of the simpler metazoa, where a fusion of several stimuli into one special form is not yet possible. Volkelt maintains that a fly out of the web is not cognized as the same thing by the spider as a fly in the web. Experiments have shown that bees and wasps will not enter their hives if a slight change in the environment has taken place. Washburn makes a further point in this connection by showing that perception is itself conditioned in animals like raccoons, elephants and monkeys by the fact that for the first time objects can be voluntarily moved in their surroundings. These perceptions are therefore more like those of man. Man has emotions, then, because he cognizes his external world in its various relations as well as in terms of objects and events. Out of the two hundred or more emotions analyzed in our laboratory, fully three fourths show the significance of ideational factors which could not be present in lower animal forms. Our emotional reaction to the dead human body, even when much disfigured, is greatly modified by our theory of the relation between body and personality. Before we learn that the most nerve-racking groans may be emitted by a totally anesthetized subject under a major operation, our emotional responses are entirely dependent upon the perception of these groans as a index to human suffering. But even here, as in James's illustration of his own childhood experience with the bucket of blood, the inherited part of the total pattern is sometimes hard to subdue by reason or by learning. All that we now contend is that the emotion, like many of our other human experiences, may be much modified in terms of the actual conditions cognized.

Our experimental results in the laboratory again clearly show that we are lucky if the same environmental situation brings forth the same emotion, or any emotion at all, in every individual tested. In one outstanding case, a pistol presented suddenly to the head in an otherwise peaceful situation did not elicit the usual emotion of startle or fear in a female observer, but only the

[10] T. Ribot, "The Psychology of Emotions," 1897, p. 8.

comment, "What a rusty old pistol that is." In the northern timber lands she had frequently slept with a firearm under her pillow while on cross-country hikes, and her somewhat peculiar experience had modified the usual emotion almost to the vanishing point. Only under rare circumstances and with much forethought can we set up experimental conditions that will arouse approximately the same emotion in a score or more of observers.

The fact that the development of the mental life must be ripe for the proper emotional experience was definitely shown in experiments carried out by G. S. Gates with the author's photographs of emotional expression. Expressions of pleasure were recognized by the majority of the kindergarten group, pain by a majority of the first grade, anger by the third grade, fear in the fourth grade, surprise and wonder in the sixth grade, but scorn was recognized by only 43 per cent. of the fifth grade. Apparently "scorn" is one of the emotions that require a background in actual experience. The growth of emotional reactions as well as the wide individual differences have been noted in our Child Welfare Station by Marston who found an increasing tendency in children to inhibit outward manifestations of emotion as they grow older.

We intimated above that mental development on the side of feelings does not stop with emotion. Already in classifying the emoticns distinctions have been drawn within this category between the primitive emotions and the subtler or higher emotions. In man, so far as we can discover, we have the first appearance of that stage in the emergent evolution of the complex mental process known as sentiment. Here the hereditary factor is not nearly so strong as it is in emotion, and the idea has largely replaced the percept as the basic mental process or function. We often actually see and hear objects which arouse sentiments, but the sentiment itself is conditioned primarily by the ideational content and the abstract meaning which the percept conveys. Not the national flag as a visual perception or a funeral march as a auditory process *per se* but the abstracted meaning that lies behind these experiences stirs up our sentiments. This point is also raised and developed in several recent books on wit and humor. The type of joke that a person will enjoy might well be used as a test of his mental culture. Hence the low rating which puns usually receive!

In fine, then, our point is that we have emotions because, first of all, the mental life contains the feeling component which has grown up side by side with our cognitions, but in not nearly so detailed a manner as they have. We must not forget that the agreeableness and disagreeableness of experiences have long been with us in the steady development of the mind. The next step to a pleasant or unpleasant sensory experience was the emotional pattern with its inherent cognitive processes and its much more elaborate systems of response. When mind was developed to this stage of complexity the configuration of emotion emerged and gained scientific recognition through appropriate terminology. The percept or idea of a total situation, event or object first made this possible, and probably in the following order: first, the percept or direct apprehension, and then the idea of situations not physically present or relationships not physically apparent.

Many attempts have been made to answer our main question in terms of bodily processes of almost innumerable sorts. We have already indicated some of these references in our historical survey. But it seems that no sooner is a physiological process scientifically investigated than it is seized upon by avid psychologists in explaining the emotions.

Here is the inventory: expansion and contraction of protoplasmic tissues; involuntary movement of pursuit and avoidance; extension and retraction of voluntary muscles; changes in respiration, in circulation, in blood pressure; reverberations in the visceral region; volumetric changes in various parts of the body through extension of the capillaries with blood; tumescence and detumescence of the sex organs; secretions of the endocrine organs and presence of their products and of hormones in the blood; changes in electrical resistance and in the output of electrical energy; appearance and disappearance of Nissl substance in the brain cells; alterations in the rate of metabolism. To try to account for the mental life or any phase of it solely and primarily in terms of bodily changes is ridiculous in the face of the history of thought. The extreme position in this regard is well illustrated by Berman's widely circulated book called "Glands Regulating Personality," and Clarence Darrow's doctrine that criminals have only their glands to thank for their misdeeds is an offshoot of this philosophy. But it all reminds one of Mercier's statement that this is like "putting beefsteak into a sausage machine and pulling out a sonata" and James's remark that we might as well look somewhere in the train of cars for the friendship that exists between the brakeman and the engineer.

Luckily, however, this extreme position has not been held by most experimental psychologists. It is a restricted group of behaviorists, modified or pure, that have made the emotions equivalent to organic response. This group, however, leaves all consciousness as direct human or lower animal experience also out of account, so we have nothing else to expect from them if they are at all consistent. Our position, however, is as much at variance with that which attempts to *explain* emotion wholly in terms of one or more bodily responses as it is with that which *describes* emotions by means of these same responses. As has been noted above, explanation can come, in part at least, from the genetic development of mind itself. We have seen that not only must mind possess the ultimate feeling of pleasantness and unpleasantness, but it must have developed to the stage beyond the point where simple sensory qualities are pleasantly or unpleasantly colored. It must have arrived at the plane of perceptual experience of objects, events, and relations between these before it can have emotions. When they are affectively colored and have certain widespread organic responses accompanying them we have the corresponding emotions.

We have noted that the bodily manifestation of emotion has had a long history; it dates back to phrenology, which tried to diagnose character through the contours of the head and the expressions of the face. Darwin gave it renewed emphasis through his work with animals. But it was brought to wide notice in 1884 through the dramatically expressed statements of William James, since embodied in the James-Lange-Sergi theory. Three investigators had independently come to approximately the same conclusion. As usual, the theory had long been "in the air." In a scholarly note,[11] Titchener presents a long list of writers, especially French writers like La Mettrie and Cabanis, who had anticipated James and to whom James curiously enough gave scant notice. James's position was that the percept of the object or situation was directly followed by an inherited organic response and only when the latter "reverberated in consciousness," *i.e.*, was felt as such, did the emotional experience arise. In his own words, "Our feeling of the same changes as they occur

[11] E. B. Titchener, "An Historical Note on the James-Lange Theory of Emotion," *Amer. J. of Psychol.*, 25: 427–47, 1914.

IS the emotion." In obverse form a few pages later on he says, "If we fancy some strong emotion, and then try to abstract from our consciousness of it all the feelings of its bodily symptoms, we find we have nothing left behind. . . ." He arrays many facts and findings in support of this position.

Two negative criticisms were brought to bear on this proposition: the pleasant and unpleasant attributes of feeling were left out of the formula and furthermore, as Angell soon pointed out, everything depended on the temporal sequence of events which under the conditions could hardly be introspectable. It mattered most just when the emotional experience was felt; was it felt as emotional when the percept occurred at the beginning of the experience or later? The theory would be overthrown if it were clearly shown that the bodily response did not happen until the emotionally colored percept was fully under way. This is the attitude most psychologists took in connection with emotion. The situation as regards the inclusion of affection was amended by James in 1894 with the remark equivalent to: "You foolish critics, of course you should have understood me better." But that again spoils the picturesque formula.

It will be clear at this juncture that the bodily responses have an all-important bearing on the emotions and that their place in the general scheme of things must not be denied. The writer's protest is rather against making the mental fact of emotion as a livable experience equal to, or the same as, some chemical or mechanical change in the body. Since Driesch's[12] excellent work on the relation between mind and body, now in its third edition, one can no longer maintain even a parallel relationship between mind and body. Mental processes like emotion, perception, imagination, ideation and thought do not run parallel to corresponding neurological, muscular and glandular secretions, if by such parallelism an efficient causal connection is implied: mind working on the body or the body working on the mind. The relationship between the two is more satisfactorily likened to two sides of the coin. Ordinarily the two sides can not be seen at one time. You look at one side and you comprehend only the mind and then you look at the other side from another point of view and you understand only the body. Both can not be discussed or described in the same terms or from the same line of regard. This is known as the "aspect" theory and dates back 250 years to Spinoza. It is becoming more and more widely accepted to-day, and in its modern version has been advocated chiefly by Warren. What the coin is actually made of or which side is front and which is back are the most difficult questions of all time. From the author's point of view, the universe can be more readily translated entirely and exclusively in terms of experience, that is, into an objective idealism, than into anything else. That may be due, however, to the fact that he is a psychologist, not a physicist, and further to the fact that we all are mentally anxious to simplify the universe and to reduce it therefore to one and only one underlying principle, be that the *idea* of Royce or the *electron* of Weiss.

With this understanding, then, let us return to emotion. Experimental facts point first to the conclusion that throughout the entire gamut of our life of feeling, movement has played an important rôle from the biological point of view. In the lowest forms in which movement can take place, in the unicellular animals, like the amoeba, the vital tissue protrudes in the direction of favorable stimuli and withdraws from harmful stimuli. When we have reason to believe, then, that sensations are first differentiated off from a common senti-

[12] H. Driesch, "Mind and Body: A Criticism of Psychological Parallelism" (trans. by Besterman), 1927.

ency or generalized feeling, and when they are affectively colored as pleasant or unpleasant, movement is already tied up with the experience. When this movement is felt again as sensation it enriches the affective experience still further. Often, like the moth flying into the candle-flame, these movements lead to harmful results, but, on the whole, all along the line, reflexes have been built up in the more and more complex animal forms on the basis of withdrawal from the painful and harmful and the reaching-out after the pleasant and beneficial. Even to-day, with the great deposit of the experience of the race within us in the form of reflex and instinctive behavior and the added experience of our educators and our own experience to draw upon, we still are repelled by the ugly face of an individual, though he be a Socrates, and feel attracted to a beautiful woman like Lucrezia Borgia who may be nevertheless an undesirable member of society. The writer has wondered whether Socrates would have been condemned to drink poison hemlock had he been a handsome man. The public must be brought to an abnormal emotional pitch to sanction the execution of an attractive woman for high crimes committed.

And so the musculature has been developed along with the growing complexity of mind to express organic needs. The bodily development does not rest there. At the same time all organic processes have been geared into the mental life, even directly or indirectly the growth of cell tissue and the very last metabolic process in the life stream. If we learn anything from physiology today it is the growing belief in the intimate interconnection of all of our bodily parts and functions—the same principle that finally overthrew on the mental side the so-called faculty-psychology of separate and independent mental capacities. The healthy living individual is an integer. Since emotions for the most part are so old and have held such an important place in the adjustment of the body to all sorts of situations, they involve these bodily processes to an outstanding degree and to an unusual extent.

Not all of these bodily processes are felt directly in experience, but many of them are, and others are felt indirectly. The tensing of muscles, the flushing of the face, the dry lips, the chills up and down the spine, the moist palms, are among the numerous items reported by our observers in the laboratory. These items even when only vaguely felt complete and enrich the emotional picture. The pattern is formed out of this bodily background, and each different emotion from our preliminary experiments gives a different and yet consistent arrangement of these details. They add depth to the experience and make it intrinsically personal since they tie the objective situation to ourselves and our bodies. The movements executed in the playing of familiar musical selections no doubt add to the enjoyment of one of these selections when it is later heard, since the sensations attending the movement are, at least in the writer's case, recalled as images in memory.

All this may have seemed like wandering through a long and circuitous path. The writer's snythetic answer to the question of why we have emotions is: first, because we have a mind developed to the point where entire situations and events, together with their meaningful relations, can be directly perceived or imagined. Without the ability to cognize our surroundings on this level we could never have an emotion. Secondly, behind it all is our possession of likes and dislikes, pleasantnesses and unpleasantnesses, the whole affective coloring of life. And finally our bodily accompaniments, the entire list of processes enumerated above, the movements of arms and legs, facial expressions and the like, have not only a social value, but with those that are implicit and unobserved have a reflex value on ourselves, enriching the experience and relating it to an important part of ourselves, namely, our bodies.

TROPICAL LIFE FOR WHITE MEN

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HAVING lived for nineteen years in the tropics, in Singapore and in different parts of the Philippine Islands, I was naturally very much interested in the extracts appearing in *The Literary Digest* from an article on "Tropical Life as a Factor in Human Evolution," originally appearing in THE SCIENTIFIC MONTHLY from the pen of Professor Ralph E. Danforth, of Massachusetts. I was the more interested because the results of my observations and my own experience in the tropics have brought me to exactly the opposite conclusions reached by Professor Danforth.

The "stupid notion" that tropical conditions lead to indolence and degeneration in man no doubt "clings with surprising tenacity" because it is based upon actual facts. Professor Danforth is quite right when he says that many of us, after a survey of the venerable civilizations of the Nile, the Euphrates and Tigris (more semitropical than tropical, by the way), will be "inconsistent enough to say in the next breath that man degenerates in the warm countries," for he certainly does, if they are warm enough. Where are the sons of the great builders of those civilizations? Where are the descendants of the builders of the great temples of Yucatan, Indo-China and Java? If they exist at all, they are certainly degenerate sons of noble sires.

Professor Danforth, in his second paragraph, as quoted by *The Literary Digest*, apparently makes the *survival of the unfittest* in the tropics responsible for the present decadence there as compared with centuries ago, in which he opposes a famous scientific law now being generally recognized. Is it not the fact, however, that except as new ideas carrying moral force have come at various times to stir tropical peoples into temporary activity, there has been a general decadence of the whole race in the past, whatever may be the tendency at present?

I quite agree with Professor Danforth's warm panegyric of the tropics. That is why I am here. But the fact is that the more tropical they are the more beautiful they are, because the more suitable for vegetation, though less suitable for man, particularly the white man. If Professor Danforth has any facts to show that the white man ever produced a magnificent civilization at sea-level near the equator, the world is awaiting that information. As a matter of fact, such lands are peopled by brown or black people. And "there's a reason." Professor Danforth tells us that man's "physical requirements are undoubtedly for a very mild and genial climate," with which statement I can quite agree; but would he call the equatorial regions "mild and genial"? I find by the official statement that the temperature in the sun here on New Year's Day, just passed, was 157 degrees Fahrenheit. Is that any more "genial" than the thirty degrees minimum which I found at San Diego, California? Or is it any more "mild"? These terms should be used circumspectly. Just as the white man has had to take centuries to fit himself (or rather to become fitted by the conditions surrounding him) to life in northern climates, just so has the brown or black man survived because he has grown to

conform to local conditions. His ancestors or his predecessors, whichever they may have been, were very different men from the equatorial man of to-day. They did wonders, which man can not do in the tropics and survive. The result?—a race which is wise enough to take bountiful nature as a kindly mother and not a harsh taskmaster.

Professor Danforth gives away his whole case when he says, according to the *Digest*, that "increasing numbers of folk with good heredity will probably colonize the pleasanter regions of the tropics, at moderate altitudes." When you get into these altitudes you are not where the great civilizations of which he writes were, neither are you where the great masses of people to-day are, where there is industry or avocation for "folk of good heredity," or where there is any real object for such folk to migrate. If Professor Danforth wants to argue that tropical life is good for the white man, because it is "mild and genial" (157°), let him base his arguments on those parts of the real tropics, such as Singapore, where man throngs the seacoasts.

We are told that we may rise above the dusty streets, if we only "plan aright." But if this is a good place for the white man he must take conditions as they are, as he does at home. Few of us indeed can afford to build or even live in skyscrapers, far above the dusty roads. I live myself in the third story and find dust on my mirror when I rise every morning in the dry season. If the tropics are so good for the white man, why these extraordinary precautions to rise above the dusty streets? We don't do it at home.

In conclusion, a few of my own observations will suffice to show the effect of tropical life upon white and other peoples. In the Philippine Islands, for instance, there is a variety of tribes, mostly of Malayan stock. They all, with one exception, look much alike when dressed alike, but there is a great difference in their characteristics. The Visayan, who lives in the southern islands, is slow and easy-going, with little ambition and no initiative. Wherever this is not true, there will be found to be an admixture of Chinese or other alien blood, comparatively new to the country. The most industrious, the most pushing, the most ambitious of all the tribes in the Philippines is the Ilocano, which furnishes nearly all the emigrants to the Hawaiian Islands and to the United States. Their habitat is in the northeastern part of the Philippine group, where they are many degrees farther from the equator than the Visayans and also face the strong breezes which sweep across the Pacific. Yet the two are brothers in blood.

The habit of running amuck (in Malay amok) is a characteristic of all peoples of the Malay race living near the equator, but is unknown among the same peoples far from the equator. It is certainly a characteristic superinduced by the rays of the torrid sun. The same rays have sent many a white man crazy, some of whom I have personally known. In fact, I dare to assert that we would every one of us go crazy if we lived under the same conditions as the Malay. Every white man who lives at sea-level near the equator learns that he has to wear a specially constructed hat to protect his gray matter from turning black, figuratively if not literally.

Is it a good place to encourage the white man to settle in, when he has to exercise every sort of precaution to preserve either his physical or his mental health? I trow not, because there are few of us with sense enough to be constantly on the alert to take the essential precautions. The result is that the ordinary white man deteriorates here mentally, physically and morally. This is

shown by many facts. For instance, it is known to every white man here that death comes with a suddenness unparalleled anywhere else on the globe. It is an old saying, repeated to newcomers, "You are at work to-day, sick to-morrow, dead the next day and buried the day following." Why? Simply because the white man's body is so weakened by the debilitating effects of tropical life that he falls a ready prey to a disease which he would soon shake off in colder lands. The first mental faculty lost is the remembrance of names. I have lost that completely here and on going back to the United States recovered it fully in less than a year. The will power is weakened and this leads to vices which aid the climate in bringing premature decay. The children of white parentage do not get reddened, as one would suppose who has never been here (for they do at home in hot weather), but on the contrary they become a chalky white, which betrays sadly impoverished blood. Even adults frequently get the same way. Once you get that way there is no regaining a healthy color without a return to a colder climate.

A final bit of evidence that I would cite to prove the inevitable deterioration of the white man in the tropics is this: His descendants, when he has mingled his blood with any of the native races, will become more or less degenerate (if they remain in the tropics), in almost exactly the proportion in which they retain or lose the paternal color. I am aware that there are many exceptions to this rule, and some may attempt to dispute it altogether, but it is the settled conclusion of long years of study and personal investigation.

SOME INSTANCES OF SUPPOSED SYMPATHY AMONG FISHES

By Dr. E. W. GUDGER

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THAT the higher animals, birds and mammals, frequently manifest sympathy for their wounded comrades is a matter well known to students of natural history. Most of us have read how the comrades of a wounded elephant will support him on either side while he is endeavoring to make his escape. I am able to quote just here from the well-known naturalist, Abel Chapman, in his book "Savage Sudan" (London, 1921, pp. 157 and 283) two definite cases of similar kind. He had wounded a lechwi (*Onatragus megaceros*), and thus describes what took place after one of its fore legs had been broken by a shot:

> He had already stopped twice, and appeared on the point of abandoning further effort, when his sable pal, with at least one of their tawny consorts, deliberately turned back to the rescue of their disabled friend—surely a beautiful example of animal sympathy. Supported thus on either flank, for a while my quarry gamely struggled onwards; but it soon became obvious that the effort was beyond his ebbing strength. Then the gallant auxiliaries had perforce to abandon their attempt, and soon the whole herd proceeded at full speed inland.

Chapman put the buck out of his misery and then shot the other buck which had again come back to assist its comrade. Later he wounded a baboon and he thus described the action of its companions:

> Suddenly the rest of the troop, which meanwhile had utterly vanished, reappeared, two or three supporting their stricken leader on either side. Being now still more reluctant to fire, the result was that the ambulance squad reached a patch of thick bush and therein I lost them. A similar incident occurred the following year on the Dinder River.

Coming nearer to our subject, at least so near as to a water-dwelling mammal, the grampus, R. J. Daniel ("Animal Life in the Sea," London, 1925, p. 85) quotes from a writer named Buchanan that in hunting the grampus from a small boat in the Mediterranean:

> One was killed and a second wounded by a harpoon, whereupon two others ranged themselves on either side of the boat, and attempted to crack the timbers by squeezing with all their force, and in this plan they would have succeeded if the dead grampus had not been already hauled alongside; this acted as a fender and raised the boat out of the water a little so that it avoided the fury of the attack.

This is all very well, says the reader, for "You are dealing with the higher vertebrates with well-developed brains; but what about your fishes, cold-blooded vertebrates, the lowest of the back-boned tribe?" Let me answer first of all in general terms that while they are the lowest of the vertebrates their brains and nervous systems are far from being rudimentary structures. Nor are they wholly devoid of intelligence. This can be attested by any one who has tried to lure from his hiding place under a stump or a shelving rock a wary old trout who by reason of his size and cleverness is acknowledged master of the particular "hole" in the stream wherein he has taken up his residence.

At the Tortugas (Florida) Laboratory of the Carnegie Institution of Washington, a school of gray snappers (*Neomaenis griseus*) used to play around the western dock to feed on the scraps from the kitchen. When any one approached, these fish would turn slightly on one side,

would cast a cool and wary glance at the intruder and slowly move off. I have elsewhere[1] described their behavior in some detail. None was ever taken with a hook in the daytime. Many years before, Dr. C. F. Holder fished for gray snappers at Tortugas and only occasionally hooked them even when he used a long slender wire leader *embedded in the sand.*

The most wide-spread manifestation of supposed sympathy among fishes, and one witnessed by many travelers and possibly by some of my readers, is that of the pilot fishes, *Seriola zonata,* and *Naucrates ductor,* small mackerel-like fishes which are frequently found associated with sharks and which seemingly show great excitement and distress, manifested by dashing wildly about, when the shark is drawn to a vessel or wharf and is pulled on board. This is of course open to the construction that the shark, the pilot fish's home, is being taken away from him, hence his excitement and apparent distress. However, so far as manifestations of pity or sympathy among fishes are concerned, I had given no attention to the matter until the following incident was noted. At Tortugas in 1913, while trolling one day between Loggerhead and Bird Keys, I had a heavy strike. Pulling in the fish hand over hand I brought to the surface a large barracuda. Remarkable to say, this had close on either side a barracuda nearly as large as itself. These had their heads in the region of the right and left pectoral fins of the hooked fish It looked as if they had laid hold behind on the breast fins of their captured friend and were helping him hold back, and chief engineer John Mills, who was with me at the time, so averred to the men's mess. And it must be confessed that it did seem as if all three fish were pulling back on the line. When the captive was brought near the boat its two companions disappeared.

Record was made of the matter and later an account of the incident was published in an extensive monograph on the barracuda, but without any attempt at explanation. In fact nothing further was thought of the incident until, as editor of the index volume of the "Bibliography of Fishes," I chanced on certain references to seeming manifestations of sympathy in fishes. Notes were made of these and of like instances in various books on fishes and fishing, and were filed away. Later, particular accounts were sent in by friends and correspondents who learned of my interest in this matter. And now it seems worth while to bring these together in an article bearing the title above.

Edward Jesse in his "Gleanings in Natural History" (vol. I, London, 1832, p. 75) gives the earliest record known to me of what might possibly be conjectured as a manifestation of piscine sympathy. During the spawning season he caught a female pike, whereupon another fish (presumably a male) followed her to the edge of the water and refused to be driven away.

The next account I have is from the pen of Leon Bucek,[2] who in 1879 was an eye witness to the following incident. A friend of his had an aquarium inhabited by a number of small turtles. These he fed on gudgeons, and Bucek describes carefully how the turtles would stalk the gudgeons. Then he adds:

> Happening one day to be passing the tank, I noticed a little fish in imminent danger of being devoured in this way. I thought to myself, "Poor little devil, it's all up with you!"—when I saw swimming up an older and larger gudgeon, which also, it seems, had noticed the murderous intention of the turtle. "What will happen now?" we asked one another. The

[1] E. W. Gudger, "Notes on the Behavior of the Gray Snapper (*Neomaenis griseus*), a Common West Indian Fish," *Natural History,* 1924, 24: 253–254. Fig.

[2] Leon Bucek, "A Brave Gudgeon," *Fishing Gazette,* London, 1879, 3: 544. Translated from *Deutsche Fischerei Zeitung,* Oct., 1879.

gudgeon did not keep us waiting long for the answer. With extraordinary exertion and powerful strokes of the tail he squeezed himself past the turtle up to the poor victim, covered him with his own body, and then, whilst splashing violently in the water, placed himself close to the young fish, pushed him forwards until he was in a more open part of the tank and out of danger—and so saved him.

R. B. Marston,[3] the well-known angler and writer on angling matters, was led by Bucek's story to relate the following incident which happened to him personally:

We noticed two very large chub swimming close together near the surface; . . . and we let . . . our cast . . . drop gently on the water just in front of the larger fish; he rose leisurely, opened his portmanteau-like mouth, and a slight . . . movement of the wrist fixed the hook in his leathern lip. After one grand rush he soon gave up struggling and came to the top again . . . we were playing him gingerly . . . , when to our astonishment the second chub now appeared on the scene, came up to the captive, and commenced swimming around him in an uneasy and most persistent way. We were so convinced from its actions that the second chub knew its companion was in danger, that we almost expected to see it lash the line with its tail to release it—indeed, we were so convinced it would come to the rescue that we threw a dead stick at it to frighten it away; it disappeared for an instant, but only to return apparently more anxious than ever. This lasted about five minutes, when chub number one . . . got the line fast . . . in a thorn bush under water. . . . There was our prize, and there was our line hopelessly entangled, and to our utter astonishment there was chub number two swimming close to the bush and not a yard from the place where we were standing and splashing in the water. The only chance of landing number one was to raise the bush bodily from the water until he could be grasped with the other hand. In attempting to do this, a thorn must have pricked him, at any rate he made another dash and we had the mortification and satisfaction of seeing him sail away free—mortification at losing a five-pound fish, and satisfaction at seeing him and his faithful friend depart together into the depths of the pool.

Francis Day ("The Fishes of Great Britain and Ireland," 1880, vol. I, p. 229) says that a school of mullets were once caught in a net at Mevagissey. Some jumped over the net while others escaped under the lead line. However, one became enmeshed. "When this was done, another came and laid beside it, and nothing could drive it away. In short, all escaped but these two." To any one who, like myself, has tried to take these bold, vigorous fish in a net, this action of these two mullets is very significant.

H. S. Thomas in his "The Rod in India" (London, 1881, p. 65) records many keen observations on the habits of fishes, and in discussing the question as to whether fishes can communicate with each other writes as follows:

Many anglers will have noticed that in playing one fish it is not infrequently followed about through all its struggles by its pair fish in the case of the murral [the snake-headed fish, *Ophiocephalus*] or by a crowd of fishes as with the Mahseer [*Barbus tor*]. Why is this? Is it merely that the others are curious? If so what is it that they are curious about? Is it about the strange demeanour of the played fish? They follow it very closely. Or can it be that the hooked fish has expressed astonishment or fear, or has asked for aid?

George A. B. Dewar, in his book "Wild Life in Hampshire Highlands" (London, 1899, pp. 126–127), quotes a Mr. Moss, who used to fish the River Test, that one season many trout were suffering with the fungus disease. He specifically noted one fish of about two pounds in weight whose head was so covered with fungus that it was evidently blind. Accompanying this fish was a smaller fish without trace of the fungus. Repeatedly the observer noted that when the sick trout came too near the edge of the stream, "the healthy one would swim inside and gently push the former in the side with its nose, and so get it out into deeper water." He was persuaded that the healthy fish had taken charge of the sick one.

Next to be quoted is an Indian angler, W. A. Wallenger,[4] who emphasizes

[3] R. B. Marston, "A Devoted Chub," *Fishing Gazette*, London, 1879, 3: 544–545.

[4] W. A. Wallenger, "Curious Behavior of a Mahseer (*Barbus tor*)," *Journal Bombay Natural History Society*, 1908, 18: 690.

Thomas's reference to the mahseer. A large specimen had been hooked and:

> As, half drowned, he was brought within view, we saw to our surprise that the captured fish was not alone! A companion of about the same size was at his side and it was only the vision of a landing net a foot from the end of its nose, some five minutes later, that induced this remarkable companion to disappear. It looked all along just as if the captured fish was receiving that support which a fellow creature much higher in the scale of Natural History has every right to look for, and the circumstances may, I hope, be considered sufficiently interesting and unique to deserve this bare record.

Sometimes the manifestation of what seems to be sympathy between the fish and its companion takes the form of an attempt to free the captive. Thus Edward R. Hewitt found it ("Secrets of the Salmon," New York, 1925, p. 147). Here is his account of what happened:

> One of the fish made a rush, took it [the fly] and was hooked. He did not jump but tore about the center of the pool. The others seemed much excited, and one of them followed him alongside for some distance and then seemed to make up his mind what was the matter. He swam ahead of the hooked fish and then made a complete turn like a somersault right at the nose of the hooked fish; his tail of course hit the leader and broke it off. The whole action took place within thirty feet and we could see it all plainly. I wonder if some of the fish we lose where we can not see them, do not get away in some such way, by the help of others. This case did not look like an accident.

It is not generally known that Zane Grey, the novelist, is also possibly the greatest marine angler of our day. In various of his works on sea angling he has related that sailfish have attempted to bite his lines in two or to cut them with their fins. In his "Tales of Fishing Virgin Seas" (New York, 1925, pp. 153–154), he tells how his brother had a sailfish hooked when another came up and tried to bite his line. Of this and other like performances he says: "I had not the slightest doubt that it [the biting on the line] was caused by the instinct of the sailfish to free its mate." In New Zealand waters, a marlin swordfish swam rapidly back and forth under his line in an apparent attempt to cut it and free its hooked companion.

Mr. Van Campen Heilner, of the department of ichthyology in the American Museum, a fisherman of wide experience, has made numerous observations on cases of seeming sympathy among fishes, and has been good enough to prepare the accompanying statement for me. He writes as follows:

> Anent the subject of sympathy among fishes, I have observed on various occasions that fishes evince something which if not actual sympathy may be closely akin to it.
>
> Once while fishing on the Florida Reef I hooked a sailfish. Immediately the water astern seemed to swarm with sailfish and I observed that my quarry was accompanied by four or five others. These rushed about at the surface in the greatest state of excitement and one fish in particular was observed by all on board to leap into the air and fall across the line on two occasions—apparently in an effort to break it and free his companion. It may be however that this was purely by chance.
>
> It is well known that when fishing for amberjack it is an easy matter to hold the entire school astern of your boat indefinitely as long as you have one of their companions on your line. Off will rush your fish and off will rush the school with him. As you bring him back to boat, they accompany him. Before taking him aboard, however, your companion should make fast to another and the performance will be repeated. As long as you have a *struggling* fish on your line, the school will remain and it is often possible in this manner to catch the entire school.
>
> It has been my experience that a wounded fish or any fish which is acting strangely or unnaturally *always* attracts others. Whether this is because other fish see an easy opportunity for capturing food, whether they believe their companion has seized a piece of food which he has difficulty in swallowing and which they may be able to snatch from him, or whether they rush toward him in a spirit of sympathy, I am not prepared to state. It may be they are seized with a kind of "mob psychology" which they are unable to resist and rush hither and thither in a state of greatest excitement. It is the writer's opinion that food is the basic cause of strange actions akin to sympathy among fishes. I can not think of a

single incident in my experiences when I could attribute unusual actions on the part of fishes to downright intelligence.

One of my former students, Dr. Louise M. Perry, of Asheville, N. C., a keen observer of natural history matters, has written me as follows on the subject in hand:

In April, 1926, I had an interesting experience with a couple of cabios (*Rachycentron canadus*). Two of us and a guide were fifteen miles off shore [near Captiva, Florida] after kingfish. We were taking them on No. 5 Wilson spoons, and had observed a pair of large fish following the boat. We thought that they were sharks until one took my spoon, when we recognized them as cabios. For fifteen minutes the big fellow fought hard while the second fish kept so close to him and followed his movements so accurately that I was not certain which fish was being played until he was drawn nearer the boat. When he was close at hand, he made a final struggle for his liberty with the smaller fish close beside him, swimming in small circles and following right to the side of the boat when my fish was gaffed and hauled aboard.

Last of all I have the following account to present from a correspondent of mine in the South Seas, Mr. Donald G. Kennedy, of Vaitupu, Ellice Islands. Mr. Kennedy has interested himself in the fishing for the oilfish, *Ruvettus pretiosus*, a mackerel-like fish taken off the reefs of coral atolls at depths of from 80 to 250 fathoms (480 to 1,500 feet). After commenting on the fact that this deep-sea fish seems to be able to survive the low surface pressure—does not die with its air bladder distended and protruding from release of pressure on being drawn to the surface—he adds further that:

All that I have seen caught were certainly very much alive when drawn out. Furthermore, some three years ago, fishing from a boat, I hooked a *Palu fala* (*Ruvettus pretiosus*?) at about 150 fathoms. He came up in the usual fashion, but I was greatly surprised to see lying alongside, as though tied to him, but quite free of both hook and line, another *Palu fala* of about the same size. The hooked *Palu*, as his head was drawn out of the water, began to struggle violently. The other immediately parted from him and swam once round the boat. One of my men attempted to spear him but was unsuccessful. He dived soon after and quickly disappeared. I attempted to elicit information as to whether this occurrence was common, but was met by a mask of that obtuseness which the Polynesian knows so well how to assume.

The data as it has come to me on supposed or inferred cases of sympathy in fishes has been set before the reader. Careful search through the general literature of fishes would probably bring to light other instances like those narrated above. Such a search would be tedious to say the least. I have, however, gone through all the recently published books, both English and German, accessible to me, dealing with animal psychology, only to find that the attribute of sympathy in fishes has not been dealt with by any of them.

However, to one who has for many years studied the habits and the behavior of fishes in their native element, and who has some knowledge of the vast literature recording the observations of others on these same matters, it is somewhat difficult not to give a humanistic interpretation to the phenomena herein set forth. For many of the things that fishes do and many of the habits that they have developed are remarkably like similar practices found among higher animals—especially in matters of nest building and the care and protection of their young.

But fishes are the lowest division of the vertebrate group. In them the brain, especially the cerebrum (the center of mentality), is poorly developed in comparison with that of the bird or the mammal. They are, in keeping with their low position, singularly indifferent to pain. Their brain powers have been developed mainly toward three ends: the procuring of food, the avoidance of

serving as food for other animals, and the care of eggs and young—in short, to the one great purpose of perpetuating their kind. However, fishes do show the beginnings of mentality, of mind, but in a very embryonic fashion as is to be expected. And it is perhaps going too far to attribute to so lowly organized an animal as a fish the high mental quality of sympathy. It seems better to reserve this attribute for the higher animals, and hence to entitle this article "Some Instances of Supposed Sympathy Among Fishes."

THE EFFECT OF INSULIN ON FISHES

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ALTHOUGH considerable study has been made of the action of insulin, since its discovery in 1922, very little is known concerning its behavior with respect to the lower vertebrates. It is to be expected, since there is a clinical application, that the greater proportion of research upon the properties of insulin would be done on the warm-blooded animals, particularly the mammals. Almost every one is more or less familiar with the fact that a large amount of human suffering has been relieved either directly or indirectly as a result of these researches. While there are not such important practical applications attached to a study of the action of insulin in fishes and the other cold-blooded vertebrates, the results are none the less interesting. However, before discussing its effect on fishes it might not be out of place to make a few statements concerning the action of this antidiabetic hormone on the mammals.

We all know that insulin causes the blood sugar of man and the other mammals to be lowered, and for this reason is used in the treatment of diabetes. It must be given hypodermically, due to its destruction by digestive enzymes when taken by mouth. It is also recognized that an overdose will lower the blood sugar to such an extent that abnormal behavior results. This abnormal behavior in some cases manifests itself in the form of convulsions which are fatal unless glucose is administered. Rabbits, for instance, get convulsions when the blood sugar is reduced below 0.045 per cent. The rapidity with which convulsions appear after insulin is administered depends largely on the size of the overdose given. They may be produced within half an hour by a sufficiently great dosage. The number of units of insulin to be used is determined by the weight of the subject to be treated.[1]

Any study of the physiological action of insulin must generally include also a study of the blood sugar of the animal or animals concerned. If we make a study of the blood sugar of a representative number of different types of teleost fishes we find that not only is there an extremely wide variation in the percentage of sugar among different species, but that there is also considerable variation among individuals of the same species. Where the individual variation between fishes of the same species is great, it becomes necessary to use a fairly large

[1] Insulin as sold by drug companies has been standardized and may be obtained in bottles of known strength, *i.e.*, there are a definite number of "units" of insulin per cc of liquid. A "unit" of insulin is described as being one third the amount of material required to lower the blood sugar of a two-kilogram rabbit, which has been fasted for twenty-four hours, from a normal concentration (0.118 per cent.) to 0.045 per cent. over a period of five hours.

number in determining the average. In general there is greater variation within species that have high sugar in the blood than those that have a relatively small amount.

The average blood sugar of the sixteen species of marine teleost fishes studied varied from less than 0.010 per cent. in the sluggish goosefish, to well over 0.070 per cent. in the more active fishes, such as the bullseye mackerel, menhaden, butterfish, etc. In general we may say that the active fishes have a higher percentage of sugar in the blood than do the sluggish fishes. For convenience we may arbitrarily divide the marine teleosts into two groups, according to the amount of sugar present in the blood. In group I would be placed those whose blood sugar averages are above 0.040 per cent., while those with sugar below 0.040 per cent. would constitute group II. On this basis the first group —those with relatively high sugar— would be made up of fishes that are moderately or extremely active, and would include the bullseye mackerel, (*Scomber colias*); common mackerel (*Scomber scombrus*); bonito (*Sarda sarda*); menhaden (*Brevoortia tyrannus*); butterfish (*Poronotus triacanthus*); scup (*Stenotomus chrysops*); rudderfish (*Palinurichthys perciformis*); eel (*Anguilla rostrata*), and others. On the other hand, group II would consist of the more sluggish fishes, such as the toadfish (*Opsanus tau*); goosefish (*Lophius piscatorius*); puffer (*Spheroides maculatus*); sand dab (*Lophopsetta maculata*); cunner (*Tautogolabrus adspersus*), and sea robin (*Prionotus carolinus*).

Now if we administer insulin to representatives of these two groups of fishes, the resulting reactions of those in each group are entirely different. If insulin is given those in the first group, for example, menhaden, mackerel or scup, we find that after a period of time, depending on temperature and the species used, insulin shock is produced which is comparable to convulsions produced in mammals. The effect of the insulin manifests itself in the peculiar actions of the fishes: loss of balance, spiral swimming and rapid darting about the aquarium followed by a period of inactivity. A few fishes have been observed to become much darker in color.[2] In some instances violent convulsions may be developed which, as in the case of mammals, are fatal unless glucose is administered.

The time required for insulin shock to develop after the injection depends, apparently, upon the metabolic activity of the animal. This has been pointed out by Huxley and Fulton[3] and by Olmsted,[2] who have studied the action of insulin on frogs and fishes. Among the cold-blooded animals changes in temperature of course influence the metabolic activity of the animal, so that, indirectly at least, the rate at which convulsions will be produced will depend on temperature for any one particular species of fish. The metabolic activity of all fishes is not the same; consequently different species of fish, at the same temperature, will have different reaction times. There is even more or less individual variation in reaction time among fishes of the same species. At 21° C. menhaden and the common mackerel developed convulsions in from one to three and a half hours after the insulin was administered. The bullseye mackerel required from three to six hours; and the scup about twenty hours. The scup is not nearly as active a fish as the others just mentioned. Contrary to expectation, a large overdose of insulin does not bring about convulsions

[2] J. M. D. Olmsted, *Am. Jour. Physiol.*, 1924, 69: 137. I. E. Gray, *Am. Jour. Physiol.*, 1928, 84: 566.

[3] J. S. Huxley and J. F. Fulton, *Nature*, 1924, 113: 234.

in fishes quicker than a small one. As long as an overdose is given it seems to make no difference about the amount.

If we compare the blood of the normal fishes with those that have been given insulin we find that a remarkable reduction in the blood sugar has taken place in those receiving the insulin. The sugar of the blood of normal menhaden averages about 0.073 per cent.; common mackerel, about 0.064 per cent.; bullseye mackerel, 0.090, and the scup, 0.060 per cent. Similar fishes, treated with insulin and bled while in the midst of convulsions, showed reduced sugar values of from 0.010 to 0.020 per cent. This reduction in the blood sugar is comparable to the reduction in mammals following an overdose of insulin, except perhaps that in mammals convulsions begin before the blood sugar has fallen to as low a level as it does in fishes. It can not be definitely stated how low the blood sugar of fishes must fall before convulsions develop. Two mackerel bled when the effect of the insulin was just beginning to manifest itself had blood sugar values of 0.031 and 0.032 per cent. These fishes, however, had not reached the convulsive stage. It is possible that there is a threshold for each species.

Relief from convulsions may be obtained by giving injections of glucose. Occasionally one injection of glucose is insufficient, and the fish after being apparently normal for several hours goes into convulsions again. Permanent relief may be obtained, however, if sufficient glucose is administered. A number of brown trout experimented upon required from two to four injections of glucose to give complete recovery.

Turning now to a study of the action of insulin on the fishes of the second group—those which are more or less sluggish and have relatively low blood sugar—we get entirely different results. If, for instance, we inject into such fishes as the puffer, toadfish, sea robin or cunner, strong overdoses of insulin, we find no visible reactions occurring. No convulsions develop nor are there any external evidences that insulin has any effect upon these fishes. The puffer and toadfish were studied more extensively than were the other relatively inactive fishes; and to large numbers of these, doses of from five to fifteen units of insulin were administered at varying intervals of time, with apparently no effect. There can be no doubt that a sufficient quantity of insulin was given since these fishes weighed only slightly over one fourth of a kilogram. Based on the responses of mammals even a single five-unit injection would have been a rather severe overdose and theoretically should have produced a reaction if the animal was at all affected by insulin. Correlated with their non-response to insulin, we find that the normal untreated fishes of this group have low blood sugar. The normal sugar of the blood of the puffer averages about 0.024 per cent., while that of the toadfish averages only 0.013 per cent. When the normal sugar level lies as low as this it is difficult to determine if insulin has any reducing action. It will be noted that the normal sugar of the blood f these fishes lies at the level of insulin-reduced sugar in the blood of the active fishes. That is, some fishes of group II normally have blood sugar as low as or even lower than the level at which fishes of group I get convulsions. The goosefish at times shows only a trace of sugar in the blood, and it was never above 0.010 per cent. in the specimens analyzed. One can readily see the difficulty encountered in trying to find if insulin will reduce the normal sugar of a fish of this sort. The goosefish is rather an extreme case and had the lowest sugar of any fish so far studied. The sea robin normally has about 0.035 to 0.040 per cent. of sugar in the blood. One specimen bled twenty-four hours after being given insulin had a blood sugar of 0.017 per cent., but no external

evidences that insulin had been administered were noted.

The sluggish fishes are not the only cold-blooded vertebrates not to be affected by insulin. Turtles and snakes apparently show no ill effects when given large doses. Why it is that some animals are so markedly affected by insulin while others are not influenced at all can not be stated with certainty at this time. It may be that animals with low metabolic activity have a different mechanism of controlling sugar metabolism than the more active species. Among the fishes a few interesting correlations can be made that in the future may throw some light on the subject. It has already been pointed out that the most active fishes have the highest blood sugar and are the ones to be affected by insulin. These active species are also our best migrating fishes, and travel together in schools, while the sluggish ones with low sugar migrate relatively little and usually travel by themselves or in small groups. Whether any significance can be attached to this correlation between activity, high blood sugar and migrating ability remains to be seen.

It is of interest to note that in many fishes insulin is not manufactured in the pancreas as in mammals, but there are islets for its production outside the pancreas in masses scattered about in the body cavity. Particularly is this true of the more sluggish fishes, such as the sculpin and the goosefish. This condition, if it exists in all sluggish fishes, offers another correlation and suggests problems that may be extremely interesting.

IN QUEST OF THE ORIGINAL REFLUX

By Professor D. B. KEYES
UNIVERSITY OF ILLINOIS

DISTILLATION and fractionation of liquids is one of the oldest unit processes in the history of chemical engineering. The modern still and fractionating column is a very simple apparatus. The underlying principles in its design and operation extend far back in history.

Figure 1 shows an example of a modern fractionating column and still used in petroleum refining. The basic features are, a heating coil at the bottom of the column, the entrance of the feed in the form of vapor or liquid at the side of the column, and a reflux condenser to return part of the condensed vapors to the top of the column. In this particular case perforated plates are used to bring the vapors in intimate contact with the liquid. Other types of plates are also used. The column operates as a counter-current scrubber or extractor. The liquid condensed at the top of the column is of

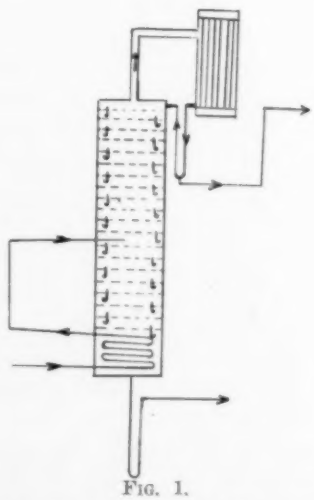


FIG. 1.

the same composition as the vapors at that point. This liquid passes down the column meeting the vapors produced not only in the bottom of the column but from the feed. The action is the transfer of the high boiling constituent from

the vapor phase to the liquid phase and the transfer of the low boiling constituent from the liquid phase to the vapor phase. The result is, the low boiling constituent comes out at the top of the column and is condensed, whereas the high boiling constituent is removed in the form of a liquid at the bottom of the column.

In looking over the fractionating columns that have been built only a few years ago in our oil refineries, we find that the basic requirements of this process have not been thoroughly appreciated. The reflux condenser has been left off and no indirect heat is supplied at the bottom of the column. An example of this type of fractionating column is shown in Figure 2. One

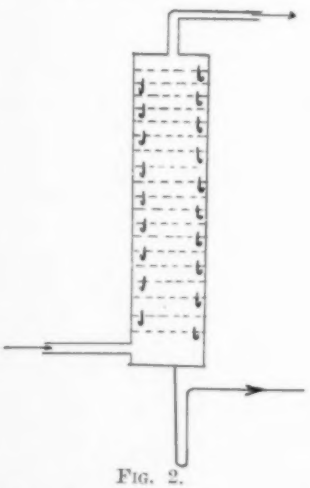


FIG. 2.

would, therefore, naturally assume that the reflux condenser was a modern invention. We find to our surprise that such is not the case; that all of these features shown in Figure 1 and Figure 2 have been known since the sixteenth century at least.

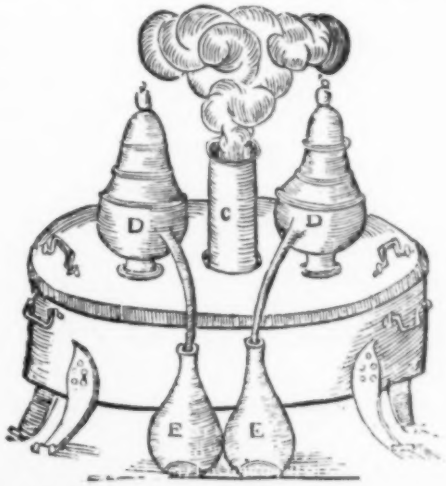
Dr. John French, of London, England, wrote a book in 1651 on the art of distillation. It will be of interest to look over some of the sketches in Dr. French's book and see how clearly he appreciated the fundamental principles of distillation and fractionation. Figure 3 shows

A hot Still.
A, Sheweth the bottome which ought to be of Copper.
B. The head.
C, The barrell filled with cold water to refrigerate and condensate the water and oyle that run through the pipe or worme that is put through it.
D, A pipe of brasse or pewter, or rather a worme of Tin running through the barrell.
E, The Alembick, sit in the furnace with the fire under it.
How to make Aqua vitæ out of Beer.

FIG. 3.

a common still of his day. It should be noticed that the still was heated indirectly at the bottom and that the distilling head was open to the air and, therefore, acted to a certain extent as a partial or reflux condenser. The total condenser consisted of a coil in the water barrel. In fact this still with its auxiliary equipment resembles very closely the moonshine stills used at the present time in our own highly modern and civilized country.

In Figure 4, Dr. French shows us the laboratory steam- or water-bath used



A, Shewes the brasse kettle full of water.
B, The cover of the kettle perforated in two places, to give

FIG. 4.

in connection with distillation. The still is heated by the boiling water within the bath and again it should be noted that the still head is outside and in contact with the cold air, thus producing the desired reflux. The steam-bath used today in our great institutions of learning shows no particular advantage over the one pictured in Figure 4. Dr. French liked to take full advantage of any cheap source of heat that he could. In Figure 5 is shown his scheme for

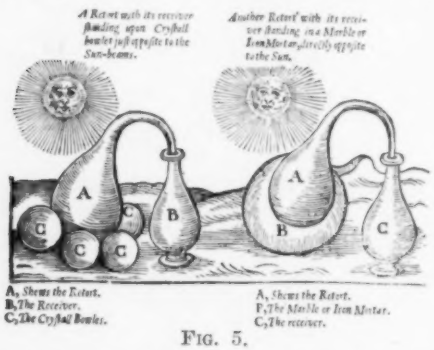

A Retort with its receiver standing upon Crystall bowles just opposite to the Sun-beams.
Another Retort with its receiver standing on a Marble or Iron Mortar, directly opposite to the Sun.
A
B
C
A, Shews the Retort.
B, The Receiver.
C, The Crystal Bowles.
A, Shews the Retort.
F, The Marble or Iron Mortar.
C, The receiver.

FIG. 5.

utilizing the sun's rays. The figure on the left has glass balls around the distilling flask. It should be noted that the flask is not completely embedded in the balls. On the right the balls have been replaced by a marble or iron mortar.

The simple art of steam distillation used so extensively in oil refining is thoroughly appreciated by Dr. French as shown in Figure 6. The first barrel

BOOK. 1. Of the Art of Distillation. 21
The manner of Distilling in Wooden Vessels.
A, Signifieth the vessel wherein the copper vessell heth.
B, The Copper vessell, part of which is in the Furnace, and part in the vessell of Wood.
C, The vessel of Wood wherein the matter must be that is distilled.
D, The cooling vessel with the worm.
E, The Receiver. F, The Trefoot whereon the vessell standeth.
Note that the greater the Copper vessell is, and the lesse the woodden is, the sooner will the Liquor boil.
This Furnace shows how to draw forth Spirits and Waters out of Vegetables, and Animalls with little cost and in short

FIG. 6.

contains the water solution while the barrel on the left contains merely water to condense the vapors inside the condensing coil shown.

A fractional condenser which has been so common in oil-refining work is nicely illustrated in Figure 7. In this case,

FIG. 7.

air condensers are used with a final water condenser. Three products are formed, one, the residue in the still on the right; another, an intermediate product in the vessel in the middle, and lastly, a very low boiling product coming from the condenser on the extreme left.

A very interesting case of multiple distillation or what corresponds somewhat to our modern fractionating column with its various plates is shown in Figure 8. In our modern columns

By Furnaces and Vessels made after this insuing figure they may be made four rectifications of any Spirit at once.
These vessels may either stand in ashes, or in Balneo.

FIG. 8.

the vapor passing from one plate to another supplies the heat necessary to keep the liquid boiling on every plate.

In this case Dr. French has used a fire under each vessel or plate in order to supply the necessary heat. It should be specially noted that each vessel has its own still head or reflux condenser.

We finally come to a clear-cut example of reflux condensation together with a utilization of a column. This is shown in Figure 9. Dr. French uses

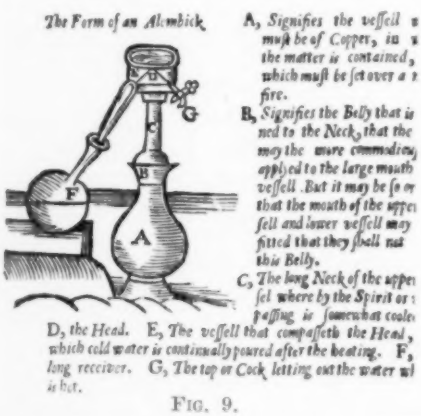

The Form of an Alembick.
A, Signifies the veſſell
muſt be of Copper, in
the matter is contained,
which muſt be ſet over a
fire.
B, Signifies the Belly that is
ned to the Neck, that the
may the more commodiou
applyed to the large mouth
veſſell. But it may be ſo m
that the mouth of the uppe
ſell and lower veſſell may
fitted that they ſhall not
this Belly.
C, The long Neck of the uppe
ſel where by the Spirit or
paſſing is ſomewhat coole
D, the Head. E, The veſſell that compaſſeth the Head,
which cold water is continually poured after the heating. F,
long receiver. G, The tap or Cock, letting out the water w
is hot.

FIG. 9.

water as his condensing medium around the distilling head shown. He points out that the water must be continually poured in and allowed to drain through the stop-cock as indicated in order to get the proper condensation or reflux. There seems to be no doubt whatever that Dr. French understood perfectly the value and necessity for a reflux condenser in ordinary fractionation.

Before going back still further in our search for the original reflux condenser, attention should be called to Dr. French's invention shown in Figure 10.

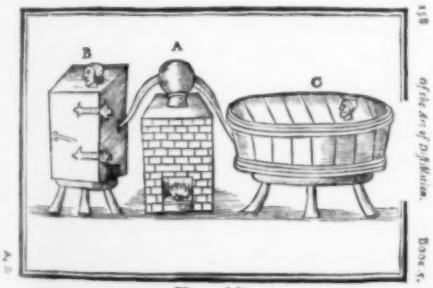


FIG. 10.

This is merely a steam distilling outfit and it might be termed the original Turkish bath. The patient on the right is not able to stand up so he is reclining in a bathtub, whereas the patient on the left is more vigorous and maintains an upright position in a steam box.

It was the author's opinion that he had traced the reflux condenser back to approximately the date of its origin. He was, therefore, very much surprized to read in an article[1] that Phillipo Ulstadio in 1525 had written a book in which the cut shown in Figure 11 ap-

FIG. 11.

peared. The column in the center contains cold water. The long neck of the flask passes back and forth through this column and finally to the receiver shown at the top. Unquestionably, this scheme will produce a considerable quantity of reflux, and what is even more effective from the fractionation standpoint, the reflux will pass a great distance before it reaches the still at the bottom, thus permitting a much better contact with the vapors than otherwise would be possible. It is also interesting

[1] "The Distillation of Petroleum for the Manufacture of Lubricating Oils," by William F. Parrish in the *Journal of the Franklin Institute*, 203: 781, 1927.

to note that Dr. Ulstadio in this same book entitled "Secrets of Nature" showed an excellent steam-bath reproduced in Figure 12. It should be noted

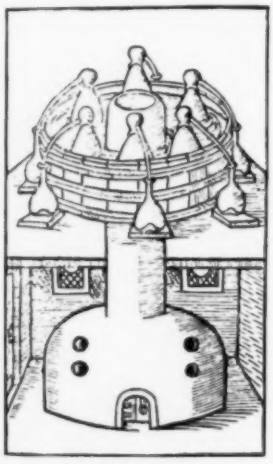


FIG. 12.

again that the distilling heads shown in this illustration act as air condensers and, therefore, provide some reflux.

In the article mentioned before[1] is still another illustration (Figure 13), taken from Dr. Herman Brunswich's book on distillation which appeared in 1500.

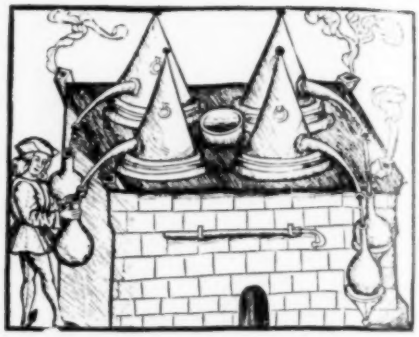


FIG. 13.

Here again we notice that the air condensers on the still heads serve as air reflux condensers.

In conclusion, the author's opinion is, the principles of fractionation and distillation used in our modern industries were probably discovered by Noah. It has been recorded that the home brew made by this distinguished gentleman was extremely potent and in all probability rectification was absolutely necessary. It can be truthfully said that though there is no particular evidence to substantiate this statement, there is no particular evidence against it and the probabilities are in its favor.

THE PROGRESS OF SCIENCE

EINSTEIN AND AMERICA

THE prominence given in our daily newspapers to Einstein's recent communication to the Berlin Academy testifies beyond question to a keen interest on the part of the general public. It is easy to ridicule this interest, and it is easy to overestimate its significance. It is not so easy to strike the balance between these opposing views of the phenomenon, and I shall not attempt to do so; but some reflections that it suggests may not be amiss.

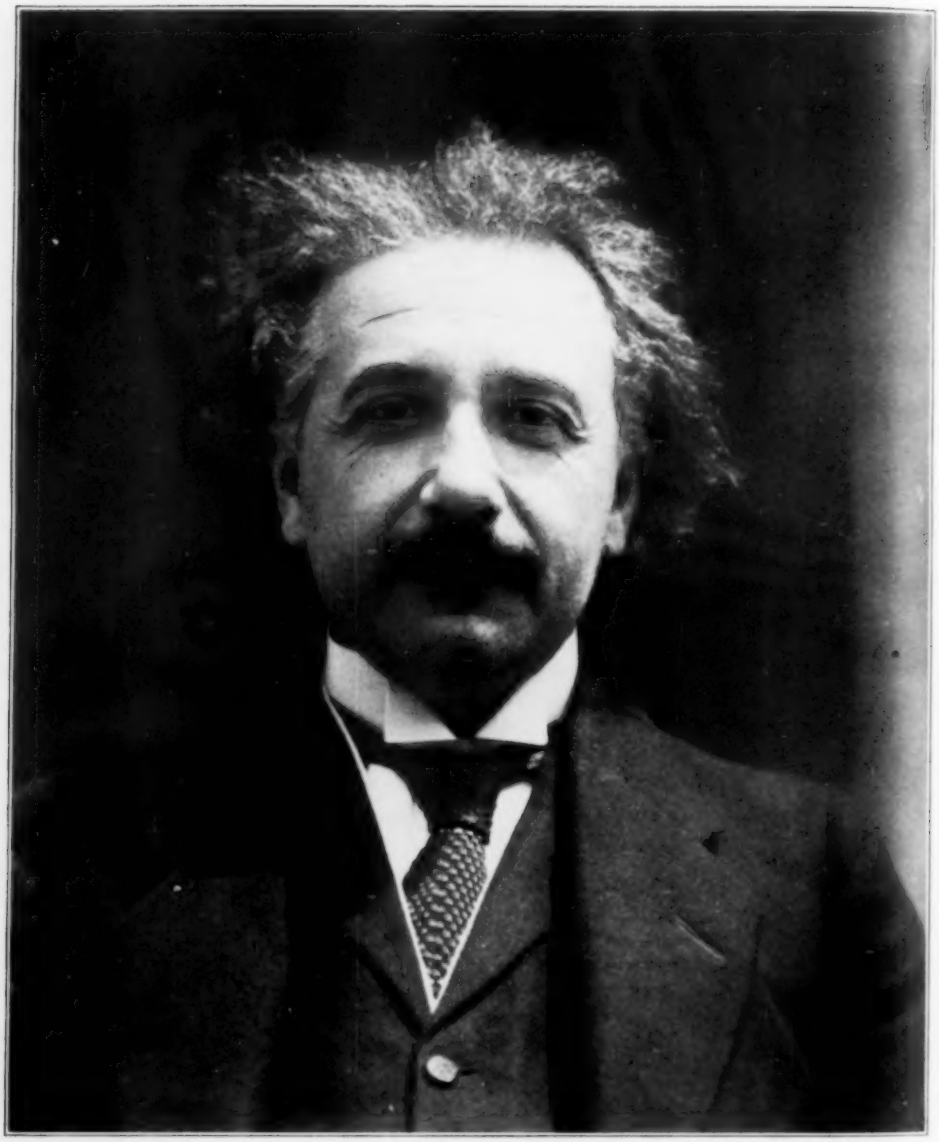
The two most remarkable examples of newspaper enterprise in connection with the Einstein paper were furnished by the New York *Herald Tribune* and the New York *Times*. The *Herald Tribune* published a complete reproduction of the paper (in English), the complicated formulas being cabled by a specially contrived method. The *Times* obtained from Einstein an article expressly written by him for the purpose, and cabled to that newspaper.

The article in the *Times* was a statement, "as simple as the subject would allow," of the nature and antecedents of the great theory which has so profoundly affected scientific thought in the past two decades. The number of those who fully grasped it was of course small. But of those who could not fully grasp it there must have been a not inconsiderable fraction to whom it gave some conception of the change wrought by Einstein and his contemporaries in our notions of the fundamentals of physics, and some realization of the depth and sweep and difficulty of the achievements of their illustrious predecessors. To do so much as this, to do it without producing in the reader any illusory feeling of having obtained more than this, and yet to do it in such a way as to thrill him with the sense of real contact with a great mind and with a stupendous theme, is a wonderful achievement.

The ferment which has been stirred up by the theory of relativity presents some interesting points both of resemblance and of contrast with the ferment which was so prominent a feature of the intellectual situation about half a century ago. Two great scientific doctrines were then in the foreground of general thought—the doctrine of evolution and that of the conservation of energy. The latter doctrine had long passed the stage of novelty in scientific circles, and even *The Origin of Species* was in its second decade; but both of the doctrines had the zest of novelty to the educated public in general, and in each of them that public found the inspiring quality that goes with the sudden illumination of a vast field of knowledge.

The universal interest with which the Einstein theory and other recent developments in physics have been received is a manifestation of the same feeling. However little one may understand either of the theory of relativity or of the consequences, scientific and philosophical, which have been derived from it, there can be no mistaking its character as one of the great landmarks in the history of thought. But nearly everybody has sense enough to know that it is hopeless for him to get more than the vaguest notion of what it is all about; in this respect there is a great contrast between the present situation and that of the early seventies of the last century.

The origin of species by means of natural selection and the doctrine of the conservation of energy were of primitive



—Underwood and Underwood

PROFESSOR ALBERT EINSTEIN

A PHOTOGRAPH TAKEN AT THE TIME OF PROFESSOR EINSTEIN'S VISIT TO THE UNITED STATES IN 1921.

—*Herbert Photo*

PROFESSOR AND MRS. ALBERT EINSTEIN

simplicity in comparison with the Einstein theories and the theory of quanta; and ordinary people were justified in feeling that they had got hold of the essentials of those two doctrines. Nevertheless it happened only too often that even the essentials of those doctrines had not been thoroughly grasped by persons who thought that they had mastered them; and accordingly many grotesque and not a few harmful inferences were drawn from them. It seems hardly credible, but nevertheless it is a fact, that a distinguished professor of sociology, a man of high intellectual endowments, deliberately asserted, in a printed book, that since popular elections are not a source of energy, they can not cause anything at all. It is one of the comforts of the Einstein situation that the profundity and difficulty of the theory are so great, and are acknowledged to be so great, that nobody will be in danger of committing in its name absurdities of any such kind.

A different kind of popular error might naturally have been expected to gain currency but does not seem to have done so. That the general interest in these startling advances springs in the main from normal intellectual curiosity, and not from a childish delight in novelties, is best evidenced by the almost total absence of light-headed observations upon the dethronement of Newton and Euclid. That the science of to-day has not discarded the science of yesterday, but has absorbed and developed it; that in its transformed state it retains, and will continue fruitfully to use, nearly all that had been acquired and established in the course of ages—these things seem to be fairly well understood by the general public. And I venture to say that this sobriety and sanity of thought is in some degree attributable to the exemplary modesty which Einstein himself has shown throughout his career. Nothing could be finer than the serene impartiality of his statements, from time to time, as to the degree in which his theories required confirmation or had received it; unless it be the total absence of self-assertion in his communications to the public, of which the *Times* article above spoken of is an instance. "Don't mind if people call you a braggart," said Don Marquis in one of his best witticisms; "leave modesty to those who have something to be modest about." Einstein certainly has something to be modest about.

FABIAN FRANKLIN

JOSEPH GOLDBERGER

DR. JOSEPH GOLDBERGER, of the Federal Hygienic Laboratory, distinguished for his work in pellagra, has died from a form of anemia which may have resulted indirectly from his experimental work.

He contracted typhus fever, dengue and yellow fever while studying these diseases. Both he and his wife subjected themselves to experiments with pellagra in order to test the manner by which this disease may be contracted.

He was born in Austria-Hungary in 1874, coming to this country with his parents at the age of six. His first work was the examination of immigrants at Ellis Island, and routine duty at other immigration stations and U. S. consulates. However, his unusual qualifications for research work were soon recognized and in 1904 he became attached to the Hygienic Laboratory at Washington, where he continued to work until his untimely death.

Dr. Goldberger's greatest contribution to science and to humanity was the discovery of the cause, cure and prevention of pellagra. For hundreds of

JOSEPH GOLDBERGER

years this disease had been known in Europe, but it was not identified in the United States until 1907. One of the dramatic chapters in the history of public health is the story of his trips through the south taken to investigate orphanages, asylums and prisons where pellagra so often prevailed. He observed the remarkable fact that in orphanages it was only the children from six to twelve years, who were not given milk and were too small to earn meat by doing chores, who were afflicted with the red rash and sore mouths and jangling nerves of pellagara.

Lack of fresh proteins in the diet causes pellagra. Adding milk and fresh meat to the diet will cure or prevent the disease. Dr. Goldberger was convinced of this in 1915, but it took him years to prove it to a skeptical world. First he produced pellagra in eleven convict volunteers, through feeding them a diet lacking in fresh meat and milk but otherwise substantial. Many times he risked his life and that of his loyal wife and fellow-workers, to show that pellagra is not caused by any germ in the blood or skin or intestinal discharges. This brave party allowed themselves to be injected with blood and with material from the sore skins of dying pellagrins. Dr. Goldberger himself and some of the others swallowed pellets made of the intestinal discharges. The experimenters did not contract pellagra, and it was thus established that it was not a germ disease.

Dr. Goldberger realized that fresh meat and milk for the poverty-stricken inhabitants of the south were prohibitive; and he finally discovered the pellagra-preventive substance in yeast. A small amount of yeast, either fresh or dried, will cure and prevent pellagra.

In a recent report Dr. Goldberger wrote that canned salmon, egg yolk and canned tomato were found to contain some of the pellagra-preventive substance, but that it probably requires nearly two pounds of tomatoes, equivalent to about one quart of canned tomato juice, to produce about the same preventive effect as a quart of buttermilk or as about half a pound of lean meat, or as one ounce of powdered yeast.

Other animals get a disease almost identical with pellagra. Especially notable is blacktongue disease of dogs. The identity of these diseases and human pellagra was discovered by Dr. Goldberger. Immediately he put this fact to work in searching for other foods that would prevent and cure pellagra. This is the task upon which he was working when taken ill two months ago.

The pellagra research was not Dr. Goldberger's only contribution to science. He discovered the cause and methods of transmission of the straw mite disease. He worked on yellow fever, dengue fever and diphtheria. He and a colleague were able to transmit measles to lower animals and thus throw light on the period of incubation and infectivity of the disease. He assisted with the influenza studies in which a few attempts to transmit the disease from person to person were made.

Important were his studies of typhus fever, which he contracted during his work with it. He was able to show that the typhus fever of Mexico was the same as Brill's disease, a mild form of typhus known to be prevalent in New York and certain other places in the United States for many years.

A bill has been introduced into the United States Senate to provide a pension of $150 a month for Mrs. Goldberger. Here is a chance for a republic to show recognition and justice to a public officer who gave his all without thought of gain. It would be helpful if the readers of THE SCIENTIFIC MONTHLY would write to members of the Congress that they may know, endorsing the bill and asking their interest.

THE NORTH PACIFIC INDIAN HALL

THE AMERICAN MUSEUM OF NATURAL HISTORY

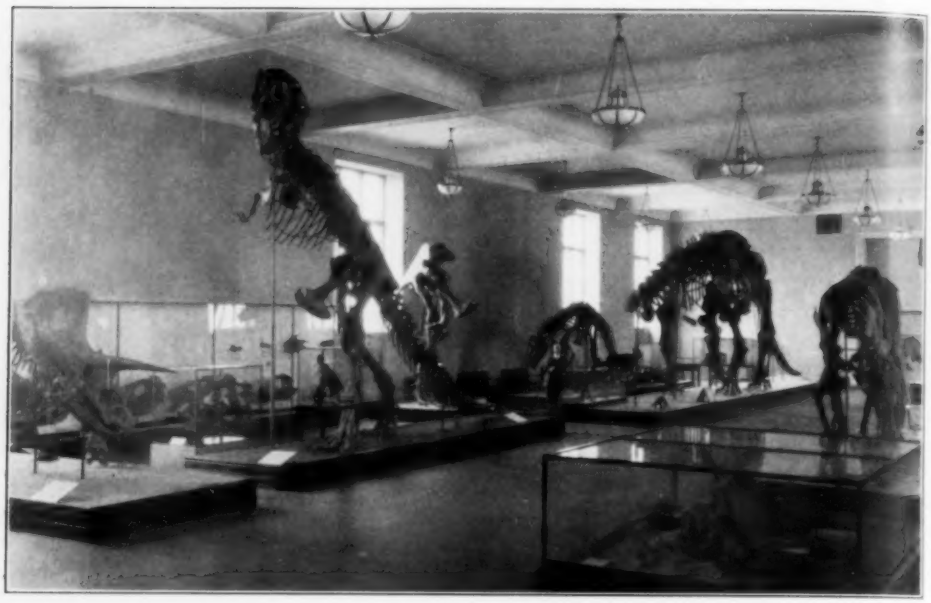
At the recent meetings of the American Association for the Advancement of Science many people became more fully acquainted with the American Museum of Natural History, which was so important a factor in the success of the convocation. The development of the institution has kept abreast with the progress of science and it may be of interest to give here some account of this great museum and its work.

The founders of the American Museum of Natural History, in the articles of incorporation in 1869, announced their intention of "establishing a museum and library of natural history, of encouraging and developing natural science, of advancing the general knowledge of kindred subjects, and to that end of furnishing popular instruction."

Commencing with a few collections which were exhibited for a number of years in the old arsenal building, which is still in evidence in Central Park, the founders, with great forethought, planned an institution which has now become internationally known as a distributor of the latest information in the sciences pertaining to natural history and its kindred subjects.

When the plans had progressed sufficiently, the trustees called upon Calvert Vaux and J. Wrey Moulder to design a series of buildings which would cover the entire area of Manhattan Square, and in 1874 the corner-stone of the present building was laid by President Grant. For many years following, Manhattan Square was considered to be in a remote and isolated section of the city, but with the passing of years it has become the center, not alone of the populated area, but as well of the scientific and educational activities of the Borough of Manhattan.

Through its articles of incorporation the museum operates under the control of a self-perpetuating board of trustees, which board has the entire direction of all the activities of the museum, as



THE DINOSAUR HALL

well as the guardianship of its halls and exhibits. The collections in the exhibition halls and study rooms are the gifts of the trustees, members and other friends and supporters of the institution, as are also the funds which enable the trustees to purchase specimens, to carry on explorations, publish scientific papers and enlarge the library.

In obtaining specimens for exhibition, the first thought of the trustees has been to secure a representative series, first from the United States, then from North America and, lastly, from all other parts of the world. When preparing material for exhibition, great thought and care are expended upon specimens for groups in order to give the visitor every environmental effect without unduly stressing it. From duplicate material, study collections have been set up which rank among the first in the world. The scientific workers endeavor to bring out, not alone the anatomical features which characterize individual specimens, but as well the distribution of the species. To do all this, a vast corps of workers is employed, numbering at present, from the highest to the lowest, four hundred and fifty employees.

In recent years the whole science of taxidermy has been revolutionized, chiefly through the intelligent effort and artistic ability of the late Carl E. Akeley, a master in his craft. The old system of stuffing animals with ragee and straw has been replaced by one which begins in the field where photographs are made, if possible, of the animal while alive. These are of great value in posing the mounted groups. Immediately after the animal is shot, measurements are made, then it is skinned and the hide prepared and packed to be shipped, as well as the skeleton.

In the mounting of animals at the museum, a rough armature is made on which a life-sized clay model is shaped just like a clay model made for casting in bronze, except that to facilitate ac-

THE NEW REPTILE HALL

curacy the skull and leg bones of the animal are used. The model is checked by measurements made of the dead animal in the field, by photographs and frequently by anatomical casts made in the field. The final result is a model, not only of the species, but of the actual animal to be used. For temporary purposes a skin could be mounted on the clay model, but an animal so mounted would deteriorate. For permanent work it was necessary to devise some light, durable substance, which would not be affected by moisture, to take the place of the clay mannikin. The material finally decided upon was papier-mâché. A mannikin of this, reinforced with wire cloth and coated with shellac, was found to be tough, strong, durable and impervious to moisture. It is impossible to model papier-mâché with the hands as one moulds clay, so the problem resolved itself into making a plaster mould of the clay model and then using that to build the papier-mâché mannikin. To make a bronze in a mould, one pours the melted metal into the mould and when it has cooled, the mould is removed. But papier-mâché reenforced with wire cloth can not be poured, and if it is put into a plaster of paris mould it will stick. The solution of the difficulty was found by taking the plaster moulds of the clay model and coating them on the inside with glue. On this glue a sheet of muslin is laid and worked carefully into every undulation of the mould. On this are placed thin layers of papier-mâché with the wire cloth reenforcement likewise worked into the mould. Every layer of the papier-mâché composition is carefully covered with a coating of shellac so that each layer, as well as the whole, is entirely impervious to water. For animals the size of a deer, two layers of reenforced composition give strength enough. When the final coat of shellac is well dried, the whole thing is immersed in water. It affects nothing but the thin coating of glue between the mould and the muslin. That melted, the muslin-covered, reenforced papier-mâché sections of the mannikin come

out of the plaster mould clean and perfect replicas of the original clay model. Of the animal, only the horns, hoofs and skull are used.

An artist accompanies an expedition to paint the background, for it is as necessary that the setting be correct as that the animals be properly and artistically posed. Also the material for the foreground has to be collected—trees, bushes, foliage and all that would go to make up a native scene. In the case of the coral reef group now under preparation at the museum, forty tons of coral were shipped up from the Bahamas.

A complete revolution has also been brought about in the matter of mounting amphibians and reptiles at the museum. Formerly such specimens were cast in wax and accurately colored by skilled artists. These had their drawbacks in that they were very fragile and chiefly because it was a very expensive process to make them "look alive." For the larger specimens, of course, the process of skinning can be employed and then mounting the skin over a mannikin. This is useful for all but the softer-bodied specimens. A method was long sought for that should retain the appearance of "fleshiness" in the object. This was finally found in a method of paraffin infiltration. It is not wholly new, having been used by Professor Hochstetter, of Vienna, for some time, and it has been in use in the American Museum laboratories for certain kinds of work for some years. It was found possible to infiltrate the bodies of reptiles and amphibians so as to retain not only their original forms but also the body colors. Even the internal organs, heart, liver and lungs, are infiltrated so that the creature is perfectly natural in appearance. The eyes alone did not take the treatment wholly successfully, so in amphibians they were replaced with pin heads and in reptiles were touched up with a little color. There is not space in the present article to explain the interesting process in detail, but the successful results may be seen in the Reptile Hall of the museum.

While the scientific work has been recorded, no mention has been made of the contact by the museum with the schools. This work has grown to such proportions that a special building, known as the School Service Building, has recently been erected by the city authorities, who recognized the importance of the museum in educational circles. From this comprehensive storehouse are distributed nature study collections, slides and films, without charge, to the city schools. This material is sent out in such quantities that it is necessary to employ five automobiles to make the distributions, and for the past year it is recorded that through these collections the museum made contacts with over ten millions of children. Museum aid is sought by teachers for the purpose of giving visual instruction on the resources of nature. By such means children are able to see life in its beginnings and life in the past, from the tiny animalcule to the huge brontosaurus.

In brief, the American Museum as now directed has for its chief objects, keeping the public in touch with the progress of science, and demonstrating the importance of research. Its halls are daily thronged with visitors who are impressed with its many activities and who realize that in this, the greatest schoolhouse in the world, may be found faithfully represented nature's lessons to the race.

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